COTTONSEED
&
ITS BY-PRODUCTS

Proceedings of the Symposium
Held from 5th to 7th December, 1958

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COTTONSEED & ITS BY-PRODUCTS

PROCEEDINGS OF THE SYMPOSIUM

Held on 5-7, December, 1958.

Sponsored at the

REGIONAL RESEARCH LABORATORY,
HYDERABAD.

by the

COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH, INDIA.

Published by the

Indian Central Oilseeds Committee, Hyderabad.
1959

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FOREWORD

A Symposium on "Cottonseed and its by-products" was organised under the auspices of the Council of Scientific and Industrial Research at the Regional Research Laboratory, Hyderabad, from the 5th to the 7th of December, 1958. I had agreed to inaugurate the Symposium but unfortunately, was prevented from doing so due to other commitments. I am glad to learn that my place was taken at a short notice by Dr. B. P. Godrej, a representative of the pioneering firm of Godrej Soaps (Private) Ltd. in the oils and soaps industries.

Oilseeds are a very important natural asset of our country but it is only in recent years that the attention of scientists is being concentrated on the problems of this industry. Production of cottonseed oil is assuming considerable importance not only because cottonseed represents an additional source of valuable vegetable oils but also a source of cotton linters required for the production of artificial silk. A target of production of 30,000 tons of cottonseed oil was set for the Second Five-Year Plan and I expect that this would be exceeded due to the efforts that are being made on all sides. We may anticipate a much higher target for the Third Five-Year Plan, say, of the order of 100,000 tons of cottonseed oil. Recently, an *ad hoc* Committee was appointed by the Ministry of Commerce and Industry to consider the problems of the cottonseed oil industry. The recommendations made by this Committee are under the consideration of Government.

Under these circumstances it was of the utmost importance to have a Symposium so that problems connected with the cottonseed oil industry could be discussed in all their aspects. Collection of the papers read in such a Symposium would be most valuable as a source of information for further action and I wish to congratulate all concerned for this compilation and particularly Dr. S. Husain Zaheer, Director of the Regional Research Laboratory, and Dr. R. Sankaran, Secretary of the Indian Central Oilseeds Committee.

MANUBHAI M. SHAH
Minister for Industries,
Government of India.

New Delhi
the 19th August, 1959

PREFACE

A Symposium on 'Cottonseed and its by-products' sponsored by the Council of Scientific and Industrial Research (India) was held on December 5-7, 1958, at the Regional Research Laboratory, Hyderabad, one of the National Laboratories under the Council. The proceedings of the Symposium are now being published through the courtesy of the Indian Central Oilseeds Committee, Hyderabad.

In an effort to ensure time for thorough discussions, the papers were called for fairly early, cyclostyled, and copies distributed to delegates about a month in advance of the Symposium. A discussion leader presided over the deliberations under each section. This procedure resulted in sustained interest in the proceedings over the period, and lively discussions.

The Symposium was organized by Shri Baldev Singh, Liaison and Information Officer of this Laboratory, and a team of colleagues. The papers and discussions have been compiled and edited for publication by Dr. K. T. Achaya, Officer-in-charge, Oils Section. Our sincere thanks are due to Dr. R. Sankaran, Secretary, Indian Central Oilseeds Committee, for agreeing to print the proceedings in so elegant a manner.

It is hoped that the proceedings will be of value to a large number of people within the country, and to those outside interested in watching the progress of exploitation of a neglected natural resource in an underdeveloped country.

S. HUSAIN ZAHEER,
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December 1959

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N. Bhojraj Naidu
K. S. Chari
B. S. Lulla
S. Raghavendar Rao
S. A. Saletore
G. S. Sidhu
S. Zainul Abideen

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INAUGURAL FUNCTION

WELCOME ADDRESS

By

DR. S. HUSAIN ZAHEER

Director, Regional Research Laboratory, Hyderabad.

Dr. Godrej, Ladies and Gentlemen,

May I welcome you, Sir, on this occasion, to inaugurate this Symposium on 'Cottonseed and its by-products' being held here during the next three days? I need hardly express how grateful we are that a person of your scientific background and creative achievements should have so readily agreed to inaugurate the proceedings to-day at such short notice in the unavoidable absence of Shri Manubhai Shah, Minister for Industries in the Government of India. Both Shri Sanjiva Reddy, the Chief Minister of Andhra Pradesh, who is also the Chairman of the Executive Committee of this Laboratory, and Prof. M. S. Thacker, the Director-General of Scientific and Industrial Research, have asked me to express their regret at not being present with us this morning. I would also like to welcome all delegate participants in the deliberations which are to follow, who have come here from quite long distances at considerable inconvenience and expense. Finally, let me welcome all those guests from this city who have responded to our invitation and are present here this morning.

A few facts regarding the importance of the subject would be in place. India produces about 1.7 million tons of cottonseed of which only a fraction is crushed and if we are to meet the Planning Commission's target of crushing 20% of all the cottonseed produced by 1961, much hard work still lies before all those connected with the industry and with research. Apart from crushing itself, there are the various by-products to be considered, since the economic utilisation of these would be essential to support the main oil industry. Also, cottonseed is, as it were, a dual-purpose seed; it is both a vehicle for the growth of cotton (a major industry in this country) and an oilseed like groundnut or linseed. Hence, perhaps to a greater degree than many other oilseeds, a very large number of fields are linked up in the utilisation of cottonseed, such as the agricultural, scientific, technological, social, economic and governmental. Agricultural aspects will include such items as cultivation of cottonseed varieties with improved contents of oil and of linters. Technical problems include the storage of seed and oil, improved methods of delinting, dehulling, crushing and solvent-extraction, and refining and hydrogenation. By way of social difficulties in this country may be mentioned a widespread but fortunately fast-diminishing resistance to feeding cottonseed cake to cattle, and to consuming cottonseed oil by human beings. It need only be stated in the latter context that the major vegetable oil in the U.S.A. is refined cottonseed oil and that 92% of the seed produced is crushed for this purpose. At a government level, tariff, imports and exports, excise duties, compulsory use of cottonseed oil in vanaspati which could form the simplest major outlet for the oil at present, the introduction of standard specifications, and the education of public opinion would all be almost vital to this growing industry.

Perhaps a word would be in order regarding the importance of this industry to Hyderabad and to this Laboratory in particular. Since the Regional Research Laboratory was and continues to be organised for the specific purpose of development of industries based on the raw materials of this region, the development of cottonseed utilisation has been of major interest to this Laboratory ever since its revitalisation in 1948. In fact, few things gave us greater pleasure than to be told by perhaps the most modern and well-equipped cottonseed utilisation organisation in this country that it was largely as a result of reading the early publications from this Laboratory regarding cottonseed that the organisation was started at all. Therefore, you will agree that it is particularly appropriate that this Symposium should be held at this Laboratory and in Hyderabad, which has a long tradition of cotton breeding and growing and produces 20% of all the cottonseed in this country.

I may add that the first Symposium after Independence on the subject of oils and fats was organised by this Laboratory in August 1950; we feel happy that an integrated Symposium on a single topic should also again be held here now. I might also indicate that this Symposium is being organised on rather novel lines. It is being increasingly realised that if a Symposium is to serve a worthwhile purpose, it is necessary that no papers are actually read at the Symposium which entails much loss of time, but are circulated well in advance, and the whole field *discussed* at the actual venue of the Symposium. This is what is being done here. A discussion leader has been selected for each category or topic, and he will guide the discussion, at which all participants have been asked to prepare their comments in advance concisely and clearly.

The Symposium was mostly organised during my absence from India and I would like here to express my grateful appreciation of the valuable work of my younger colleagues in this Laboratory in planning it so ably and with so much care and thought. I believe the convener Shri Baldev Singh will later be formally thanking all those connected with the Symposium, but I would like to add my own thanks to the Committee consisting of himself and the workers in the field of oils in this Laboratory who have worked so hard to this culmination over the last few months.

May I now request you, Sir, to inaugurate this Symposium on 'Cottonseed and its by-products' which will be held at this Laboratory during the next few days?

INAUGURAL ADDRESS

By

Dr. B. P. GODREJ,
(*Godrej Soaps* (*Private*) *Ltd., Bombay*)

Dr. Zaheer, Ladies & Gentlemen,

At the outset I wish to say that Shri Manubhai Shah, who could not come here to inaugurate this Symposium, is a very popular Minister, a proved administrator and well-versed in the technology of oils, so you will understand that it is not easy to substitute for him. Therefore, when Dr. Zaheer, the Director of this Laboratory, requested me yesterday to inaugurate this Symposium I was somewhat hesitant. I consider this as a gesture of honour and hope to prove worthy of it.

In one instance at least I am acquainted with this laboratory. Sometime ago my Company was in dire need of activated carbon suitable for the pharmaceutical industry. Some of the imported activated carbon from foreign suppliers could not be used as it was not of good quality. Almost at the last moment we were able to obtain activated carbon made in this Laboratory which helped us tide over the situation. We sometimes hear remarks that the work done in the National Laboratories is not of a practical nature. But what could be more practical than this: a research Laboratory not only making a very useful material available on a commercial scale but also contributing to the saving of foreign exchange?

I understand that this Laboratory will shortly install pilot-plant for prospecting fat splitting and fatty acid distillation. I think the Director and his team will reach their destination because they are on the right track. For many years Indian research laboratories have been trying to utilise inedible oils in India and to devise special ways and means of using them, but the distillation method is applicable to all oils and therefore it is the right approach. With this distillation plant it will be possible to obtain light-coloured fatty acids from cottonseed and groundnut soapstock. To remove odoriferous matter from neem oil I anticipate that double distillation will be necessary; after the first distillation cream-coloured fatty acids are obtained, but some of the odour persists and hence two distillations may be required. The continuously-collected still residue during the first distillation can be split and the fatty acids redistilled to increase yield and efficiency. The overall yield will thus be very high. Karanj oil which is comparatively cheap and available in commercial quantities can be ideally treated this way. The same holds good for other inedible oils.

Some papers contributed for this Symposium are so good, and contain such a wealth of information, that they are worth binding for use for reference purposes. The work done and statistics compiled will be very useful both for designing equipment in the country and for supplying information to foreign machinery makers. Perusal of the data on cottonseed makes it clear that the range of the oil and linter contents is very wide; and yet the equipment designed will necessarily have to be based on a certain quality of cottonseed. If in a certain year, *e.g.*, owing to crop failure, that quality is not available in the region, it is necessary to use a different and perhaps unsuitable kind of seed to keep the plant working, and certain sections of the plant for which valuable foreign exchange was spent cannot be utilised efficiently. This difficulty has perhaps arisen because so far data was lacking on the production of certain qualities of cottonseed and derived by-products. But as the cottonseed oil industry develops, perhaps the work of rationalisation of varieties of cottonseed to be produced and their standardisation will be considered worthwhile. I am told that cottonseed, with a high content of linters (the latter a very useful by-product, as you all know), has usually also a high content of oil. At present oil is obtained from only about 6% of the cottonseed produced and the Five-Year Plan target is about four times this figure. The content of the oil in cottonseed, about 15-20%, is such as to render it suitable for processing in continuous direct solvent-extraction plants. The difficulties about foreign exchange can be solved by obtaining long-term credits, and starting to export before re-payment of loans becomes due. Long-term loans of about three years or longer may be available from the Export-Import Bank, who would give loans to firms of repute that are considering installation of such plants. I think both oil and meal can be exported in large quantities, provided up-to-date and well-designed plants are installed. Plants ideally suited to Indian conditions are now available. During the discussions we shall try and find out what has prevented us from increasing production of cottonseed oil. Some of the difficulties may be real and we should consider and remove them, and I believe they can be solved by installing such plants. When we install plants in India, it is necessary to pay attention to all aspects of cottonseed oil milling. Often attention may be paid mainly to one part of the mill, and other items of equipment, *e.g.*, for delinting and dehulling, may be omitted. This is to condemn the scheme right from the beginning; to ensure success of the industry as a whole, it is necessary to engage the services of technologists in order to develop all the by-products. It would be wise to ensure that, in future, integrated plants are installed for cottonseed oil production in this country. Attention should also be paid to the storage of the seed. If they are old the quality of oil suffers as is very well-known.

It is quite feasible to use cottonseed oil for the manufacture of toilet soap, the production of which will increase in the years to come. For this purpose, it is necessary to hydrogenate the oil as otherwise it is unsuitable, containing a very high percentage of linoleic acid. Hydrogenation will also reduce colour. I would like to refer to the new CSIR process of refining cottonseed oil with borax. Borax forms a water-soluble and oil-soluble complex and it is claimed that the gossypol is completely eliminated. It is worth trying this process, and technologists should do so, since the dark colour of cottonseed oil, caused chiefly by gossypol, is a major problem.

We should also try to make better cattlefeed in India. I do not think proper attention has been paid to this line.

Excessive competition in some branches of the oil industry is ultimately very bad for business. The trouble with Indian industrialists, in general, is that they tread the beaten track. Some industrialists would do well to obtain proper assistance from technologists; ultimately it is that which is achieved by co-operation among industrialists and technologists which brings lasting benefit. Otherwise, not only do industries suffer but also the future prospects of technologists are seriously affected and they cannot make progress. We should have greater respect in this country for persons who have new ideas so that we can march forward.

It is said that in Russia they start work without the preliminaries to which we are accustomed. We cannot afford to copy everything they do but in this matter we can certainly emulate them and benefit thereby.

I am sure everyone will benefit by reading the papers presented at the Symposium. Sending the papers in advance is a very good idea, and enables us to have time for discussion. This Symposium has been very well organised and hence has drawn a good response. I wish to congratulate Dr. Zaheer and his team for the tremendous work they have put in in organising this Symposium. Once again I would like to say that knowing the Minister for Industries, Shri Manubhai Shah, I can say that he would certainly have come here, if he could have.

Thank you, Ladies and Gentlemen.

VOTE OF THANKS

By

SHRI BALDEV SINGH
Convener of the Symposium
(Regional Research Laboratory, Hyderabad)

Mr. Chairman, Dr. Godrej, Ladies and Gentlemen,

It is my privilege to thank all concerned. First of all I should like to express my gratitude to Dr. Godrej for having agreed to inaugurate the Symposium at such short notice in the unavoidable absence of Shri Manubhai Shah. We know him as a scientist as well as a pioneer industrialist of this country. His association with this Symposium on research and utilisation of cottonseed lends a significant importance to the underlying idea of rational utilisation of this hitherto-ignored oilseed. On behalf of all of you and the organisers of the Symposium, I express to him our deep gratitude.

Next I should like to express our indebtedness to the firms Cilag-Hind Ltd., Aryan Industries and Biochemicals and Synthetics for their kind donations towards the expenses of the 'At Homes' every evening. Their contributions are an indication of their interest in the activities of this Laboratory. We highly value their appreciation of the Laboratory's efforts and look forward to increasing collaboration with them and with other industries. On behalf of the Laboratory I should like to convey to them our gratitude and thanks.

I shall be failing in my duty if I do not convey my personal gratitude and thanks to my colleagues of the Organising Committee for having shared most of the burden of the organisation of this Symposium. But for their intensive efforts it would not have been possible to edit and bring out the pre-printed copies of the research papers sent for the Symposium, and thus focus the emphasis at the Symposium on discussion and exchange of views on the papers already studied by the participants. I feel sure their efforts will result in giving a new direction to the method of organisation and conduct of this and other Symposia to come. I should like to convey our thanks to the typists, the Gestetner operators and the office staff who were put to a heavy additional strain for the Symposium.

Our special thanks are due to the Managing Committee of the Laboratory Cafeteria who have made the arrangements for the lunches, teas and 'At Homes' for the next three days.

It goes without saying that this Symposium would not have been possible without the enthusiastic and widespread co-operation extended by scientists and technologists in research institutions and industries who have sent valuable scientific communications to it. We have received more than forty papers which have been pre-printed and distributed. I desire to express our thanks to all those who have contributed and hope that their deliberations and discussions will result in advancement in research and utilisation of cottonseed and its by-products. I thank them all for having taken the trouble to come here and participate in the Symposium.

I may be permitted to thank my colleagues of the research staff who have voluntarily assisted in the reception arrangements for the delegates. Lastly I should like to express our heart-felt thanks to you all for having come here to-day and made this inaugural function a success.

Ladies and Gentlemen, I thank you.

SECTION I

AGRICULTURAL & COMPOSITIONAL STUDIES ON COTTONSEED

DISCUSSION LEADER: Dr. K. S. Murti,
Principal, Oil Technological Institute,
Anantapur.

1. COMPARATIVE STUDIES IN THE IMBIBITION OF SOME COTTONSEEDS

By
P. J. DUBASH & R. N. JOSHI
(*Department of Botany, Institute of Science, Bombay-1.*)

1. *Comparative studies are made of imbibitional work done in different seeds prior to their germination.*
2. *The time-lag figures between maximum imbibition and germination are provided for various seeds.*
3. *Graphs of imbibitional pattern are given.*
4. *Work in progress is outlined.*

Introduction

Imbibition is a necessary precursor to germination. The absorption of water by seeds initiates the onset of conditions, like increased enzyme activity and an increased respiratory rate, which provide the energy for the growth of the radicle and its ultimate emergence through the seed coat.[3] For practical purposes the criterion of germination is taken to be the emergence of the radicle and *not the initiation of its growth within the seed coat*. Hence there appears to be a curious lacunae in the literature on germination *prior to the emergence of the radicle*. In so far as standard works are concerned [2,8] no quantitative data on the imbibition of Indian seeds and its relation to germination exist. Amongst foreign workers may be mentioned Toole[12] who worked on maize, and Avery[1] on tobacco seed.

It was felt that investigations into this neglected field would open up possibilities of research in some of the practical aspects of physiology like vernalisation and growth hormones; a vernalised seed, e.g., is one where the radicle has been activated to grow, and then further growth is stopped just prior to its emergence from the seed coat by control of conditions like available moisture and low temperatures. Similarly, auxins have been known to enhance the imbibitional pressure of protoplasm.[5]

In this investigation no attempt is made to distinguish between work done by imbibition and by osmotic pressure. The concept is in accordance with the work of Heuser[9] who states that, thermodynamically, swelling (or imbibitional) pressure appears to be identical with osmotic pressure and quotes Steinberger to the effect that osmotic pressure is nothing but swelling pressure, made evident by the external device of a semi-permeable membrane. Brooks and Brooks[4] similarly point out the lack of clear distinction between the two phenomena: "Imbibition is simply absorption of water by a system which is in effect an exceedingly concentrated solution, and can often be shown to obey the laws of ideal concentrated solutions" and further: "Imbibition in any fundamentally sound sense is not a property of colloidal systems alone but may be exhibited by homogeneous solutions of crystalloids, among which are such diverse substances as gases, molecules of solid or liquid non-electrolytes and ions of electrolytes."

When seeds imbibe water they swell and in doing so they are capable of performing work. Estimate of the work done in this fashion can provide an indication of the imbibition pressure. Detmer's Dilatometer was used for this part of the work. Data are presented on the total work done by different varieties of Indian crop seeds and compared with values obtained with available varieties of cottonseed. The time required by different seeds to achieve maximum imbibition, likewise, varies with the types studied. Thus while paddy var. Kolamba 42, requires 14 hours to achieve maximum imbibition, wheat var. Arnej 624, requires 40 hours and cotton in general requires from 8 to 12 hours. From preliminary experiments conducted so far, the graph of work done during successive short periods of imbibition plotted against time shows similarity between seeds of the same type and differences in seeds belonging to different groups.

Germination trials proved that in some seeds the time required for maximum germination coincided very nearly with the time required for maximum imbibition whereas in others there was a time-lag between maximum imbibition and maximum germination. Thus in Bajri 207 the time taken from soaking to maximum germination nearly coincides with the time for maximum imbibition, whereas in paddy var. Kolamba 42 a time-lag of about 5 hours is noticed between maximum imbibition and germination. Virnar cottonseed shows a time-lag of nearly 18 hours whereas Laxmi cottonseed shows a time-lag of over 60 hours. Further work in progress is directed towards a more detailed study of the embryology of the seed during imbibition and determination of its moisture content. This will be communicated in due course, if fruitful.

Method and Apparatus

1. *Work Done.* This was measured using the Detmer's Dilatometer as described in Detmer and Moore.[7] In all cases 10 gms. of clean air-dried seeds were used. The fluid imbibed was 18 ccs. of double-distilled water. The load used was 200 gms. The room temperature prevailing at the time was recorded. Work done was calculated in ergs/gm. of seed.

2. *Germination.* The germination trials were carried out at the room temperature prevailing in Bombay at the time. A sheet of Whatman's Filter Paper No. 1 was placed at the bottom of Petri dishes 8 inches in diameter. Double-distilled water was used to moisten the filter paper sheet. Recent trends in germination tend to use tap water rather than distilled water, but this practice could not be resorted to since the local water is heavily charged with chlorine. Seeds were first passed through a 0.1% solution of mercuric chloride to kill any fungi present on the seed coat,[13] washed, dried and then placed in batches of 50 in each dish for germination. The maximum numbers which germinated were then recorded as percentages along with the time taken. No attempt was made, for the present, to use artificial light or refinements of technique like alternate temperatures as have been recommended for cottonseed by Simpson.[11] This is because the percentage of germination achieved even with the simple method outlined above was satisfactory in all cases.

3. *Embryological Studies.* Seeds are soaked in water for different periods of imbibitional time, fixed and embedded in the usual manner. Microtome sections are then taken out in a plane parallel to the long axis of the radicle. Evidences of mitotic division are then recorded.

TABLE 1

Data Regarding Imbibition and Germination

Seed Variety	Maximum work done in Ergs.	Time taken for maximum work in hours.	Total per cent germination.	Time taken for total germination in hours.	Time-lag in hours.
Gossypium herbaceum Linn. var. Jaydhar	14.94	10	74	46	36
,, ,, ,, Kalyan	13.48	10	83	46	36
,, ,, ,, Vijalpa	13.79	10	54	48	38
,, ,, ,, Vijay	14.39	10	...	...	...
,, *arboreum* Linn. var. Virnar	12.29	10	73	28.5	18.5
,, ,, ,, H 420	10.76	10	...	...	...
,, ,, ,, Strain M 91	11.63	10	71	45	35
,, ,, ,, Gaorani 6	12.94	10	84	46	36
,, *hirsutum* Linn. var. Laxmi	9.97	10	55	72	62
,, ,, ,, M.C.U. 2	9.01	8.5	18	72	62
,, ,, ,, B. 0394	10.34	8.5	...	...	..
Pennisetum spicatum Roem & Schult. (Syn:—*Pennisetum typhvidium* Rich.)					
(1) Bajri 207	8.55	9.5	100	9.5	...
(2) Bajri 28-15	6.55	8	100	9	1
Sorghum vulgare Pers. (Syn:—*Andropogon sorghum* Brot.)					
(1) Jowar 8	11.10	9	88	43	34
(2) Jowar B. P. 53	7.62	7.5	...	...	...
Oryza sativa Linn.					
(1) Paddy var. Ambemohar 157	1.93	22	88	30	8
(2) Rice var. ,, ,,	6.00	5			
(3) Paddy var. Kolamba 42	2.54	14	92	19	5
(4) Rice var. ,,	5.32	3.5			
(5) Paddy var. Panvel 61	1.57	20			
(6) Rice var. ,,	4.84	3			
Wheat Arnej 624 *Triticum sativum* (Wheat A 624)	14.4	40	69	49	9
Wheat Niphad 4 ,, (Wheat Niphad 4)	11.5	40	...	...	...
Wheat Vijay ,, (Wheat Vijay)	13.5	40	63	52	12

TABLE 2

Distribution of Work Done per hour in ERGS/GM. of Seeds

Seed Variety	Hour:	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	Between 10th & 22nd	Between 24th & 30th
Gossypium herbaceum Linn. var. Jaydhar		8.34	2.25	0.50	0.40	0.38	0.43	0.84	0.49	0.46	0.26		
,, ,, ,, ,, Kalyan		8.58	0.91	0.37	0.33	0.50	0.70	0.73	0.66	0.39	0.27		
,, ,, ,, ,, Vijalpa		7.92	2.06	0.54	0.54	0.31	0.42	0.61	0.72	0.43	0.24		
,, ,, ,, ,, Vijay		9.01	2.54	0.37	0.54	0.48	0.47	0.31	0.24	0.24	0.24		
,, *arboreum* Linn. var. Virnar		7.33	0.53	0.61	0.88	1.05	0.69	0.40	0.28	0.26	0.26		
,, ,, ,, ,, H 420		6.52	1.64	0.45	0.33	0.25	0.42	0.45	0.16	0.30	0.24		
,, ,, ,, ,, No. 91		7.66	1.33	0.48	0.24	0.31	0.42	0.36	0.30	0.24	0.18		
,, ,, ,, ,, Gaorani		7.67	1.34	0.36	0.30	0.49	0.72	0.84	0.54	0.33	0.33		
,, *hirsutum* Linn. var. Laxmi		5.02	2.72	0.72	0.42	0.25	0.18	0.12	0.12	0.21	0.21		
,, ,, ,, ,, M.C.U. 2		5.44	1.45	0.84	0.37	0.24	0.18	0.18	0.21	0.10	...		
,, ,, ,, ,, B. 0394		6.95	1.70	0.57	0.28	0.23	0.19	0.18	0.18	0.06	...		
Pennisetum spicatum Roem & Schult. (Syn: *Pennisetum typhvidium* Rich)													
(1) Bajri 207		2.28	2.02	1.20	1.10	0.57	0.21	0.52	0.35	0.22	0.08		
(2) Bajri 28-15		1.58	1.32	1.09	0.83	0.63	0.47	0.44	0.19	.	...		
Sorghum vulgare Pers. (Syn:—*Andropogon sorghum* Brot.)													
(1) Jowar 8		2.48	2.36	1.63	1.58	0.85	1.01	0.51	0.36	0.32	...		
(2) Jowar B.P. 53		3.75	1.50	0.92	0.61	0.40	0.20	0.17	0.07	...			
Oryza sativa Linn.													
(1) Paddy var. Ambemohar 157		0.00	0.10	0.02	0.12	0.06	0.18	0.21	0.15	0.16	0.18	0.73	
(2) Rice var. ,,		3.67	1.40	0.56	0.29	0.15	0.05	...	...	...	..	...	
(3) Paddy ,, Kolamba 42		0.16	0.16	0.16	0.21	0.21	0.18	0.18	0.18	0.13	0.10	0.87	
(4) Rice ,, ,,		4.01	1.20	0.12	..	...	...	...	...	...	..	...	
(5) Paddy ,, Panvel 61		0.06	0.12	0.12	0.1	0.08	0.12	0.12	0.12	0.16	0.12	0.55	
(6) Rice ,, ,,		3.15	1.05	0.60	...	...	...	...	...	...	...	...	
Triticum aestivium Linn. (Syn:—*Triticum sativum* Lamk.)													
(1) Wheat Arnej 624		1.22	1.18	0.98	0.99	0.91	0.89	0.49	0.48	0.26	0.20	3.10	3.70
(2) Wheat Niphad 4		0.85	1.06	0.75	0.89	0.82	0.68	0.61	0.44	0.25	0.30	2.35	2.50
(3) Wheat Vijay		1.20	1.20	0.98	0.92	0.70	0.70	0.30	0.50	0.20	0.20	2.80	3.80

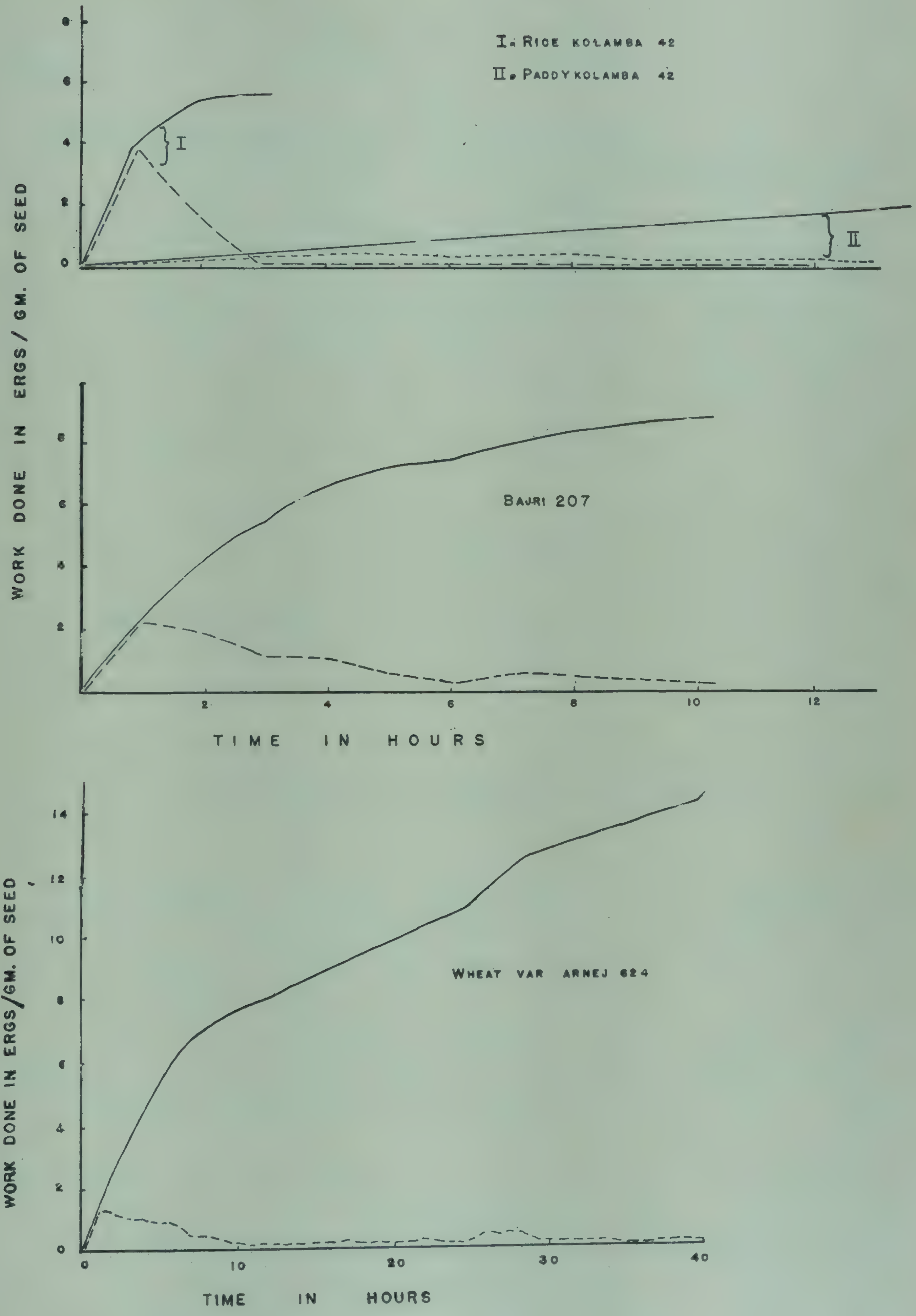

Fig. 1:— Work done Vs. time during imbibition of rice, paddy, bajri and wheat varieties. (—Cumulative ... Incremental)

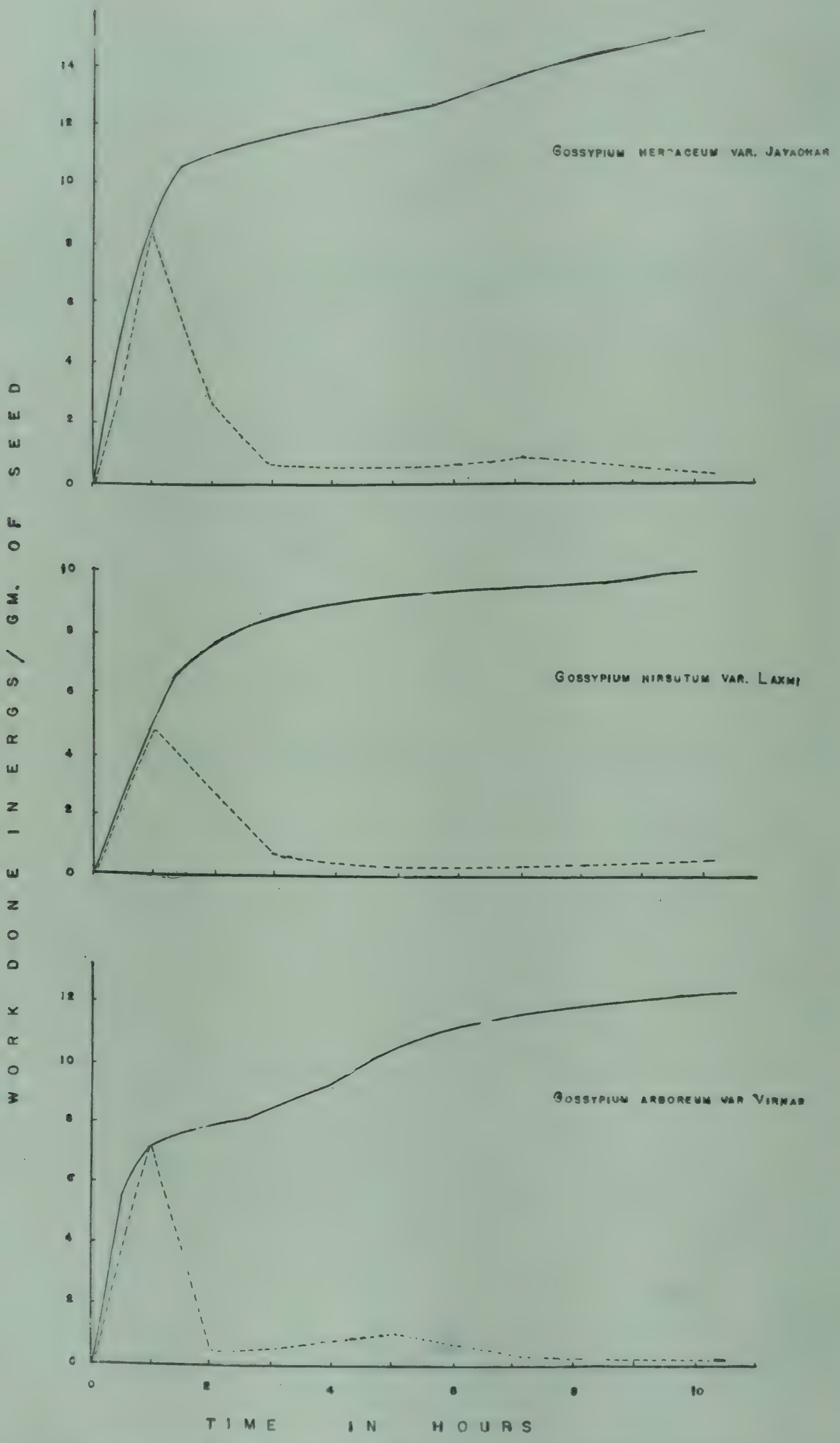

Fig 2:— Work done Vs. time during imbibition of cottonseed varieties.
(—Cumulative … Incremental)

Experimental

The work done by imbibing seeds of 11 varieties of cotton, 3 of wheat, 3 of rice, 2 of *jowar* and 2 of *bajri* has been studied. In most of the cotton varieties the maximum work done was achieved within 10 hours and only a slight increase was noted after that period. Paddy requires about 24 hours to achieve its maximum work and wheat requires about 40 hours. Hence data for all seed have been provided at hourly intervals for the first 10 hours, and in the case of paddy and wheat for 24 and 40 hours as well. Germination results have still not been concluded for all seeds: hence germination data are given only for those seeds studied so far. The embryological studies have been completed with only Bajri 207, and other varieties are under study. Table 1 shows data regarding imbibition and germination. Table 2 shows the distribution of work done/hour in ergs/gm. of seed. The data are plotted graphically in Figs. 1 and 2.

Discussion

Cottonseeds in general show higher values for maximum work done than cereals. The graph of work done in successive intervals of time is different in cereals from that in cotton. In all the cotton varieties examined so far, the largest amount of work done is in the first hour and nearly two-thirds of the total work done is achieved in the first 2 hours. This is in accordance with the findings of Shull and Shull[10] who found that the rate of moisture absorption in a variety of plant tissue is rapid at first and then gradually falls off until it approaches zero as tissues become nearly saturated.

Regarding the significance of the different periods of time-lag observed in different seeds, it may be said that even though two kinds of seed have the same imbibitional pattern their germination ultimately depends upon the permeability of their seed coat to water, as was found by Crocker.[6]

Preliminary work on the embryos of imbibing seed carried out so far on Bajri 207 shows radicle growth inside the seed coat within 6 hours of imbibition. Toole[12] has observed elongation of the coleorhiza of maize 20 hours after the beginning of imbibition. Therefore it will be of interest to gather similar data for cottonseed.

At this stage it is too early to assess the significance of these results beyond the fact that diversities of climate, rainfall and soil has produced selective acclimatization in the various types grown in different areas and these observations are a reflection of the agro-climatic conditions under which the plants are cultivated.

Acknowledgment

Our thanks are due to the Director, Institute of Science and Prof. Mrs. E. Gonzalves for providing the facilities for this work. We are indebted to Shri K. Dharmarajulu, Indian Central Cotton Committee for his encouragement, suggestions and criticisms. We also wish to thank the various Cotton Specialists who provided us with free samples of cottonseed. Last but not least we thank Shri S. S. Kelkar, M.Sc., Assistant Lecturer in Botany, Institute of Science, for his unstinted help in the embryological studies.

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2. AGRICULTURAL STUDIES ON COTTONSEED WITH REFERENCE TO THE DEVELOPMENT OF SEA-ISLAND COTTON IN THE COUNTRY

By
N. KESAVA IYENGAR
(Sea-Island Cotton Development Officer, Coimbatore.)

The Andrews variety of Sea-Island cotton, chosen for development in India to the extent of 2.25 lakh bales, yielded 1600 lb. of kapas per acre in field trials. The ginning percentage was 33, the staple length 1.5 inch and suitable for spinning 70 counts, and the lint price equal to the best imported varieties. The seed is naked and has an oil content of 20%. Soil conditions, pests and diseases and cultivation peculiarities are discussed. About 44,000 tons of surplus seed should be available for crushing in 1958-59, and technological study for its exploitation is recommended.

Introduction

Sea-Island cotton is a new introduction in the country. Researches conducted for a period of twelve years, in the former composite Madras State, indicated that this superfine group of cotton, possessing the best quality and staple length in the world, could be successfully introduced in west-coast areas like South Kanara and Malabar. In quality, this cotton was found to be as good as the Sea-Island cotton grown in the West Indies, its home. Of the various varieties tested from time to time, three viz. St. Vincent, Montserrat and Andrews, showed possibilities of successful introduction, after some acclimatisation. Of these, the fibre length and fineness of St. Vincent and Montserrat were found to be too superior for the needs of the existing mills in the country, which consumed imported cottons like the Egyptians. The prolific variety, Andrews, was however found to possess the requisite length and fineness. It was therefore selected for further development in the country from the year 1957-58. During the last two years, growing on a large scale was commenced in selected areas in the re-organised States of Kerala and Mysore. Attempts are also being made to introduce this cotton in States like Assam, which has similar agroclimatic conditions.

An All-India Sea-Island Cotton Scheme, under the control of the Indian Central Cotton Committee, was sanctioned in 1957. Its objective is the cultivation of Andrews cotton over an area of three lakh acres to produce finally 2.25 lakh bales and thereby reduce the import of foreign cotton and save foreign exchange. In addition, research on plant breeding and agronomy will also be done to improve the quality and yield, and to make the cotton suitable for spinning 80's. Selection work will also be made to evolve varieties resistant to pests and diseases. Another objective of the Scheme is to arrange for the proper ginning and marketing of the cotton produced. Suitable areas will also be surveyed, in order to make the cultivation of the cotton as remunerative as possible.

Botanical and Agricultural Aspects of Sea-Island Cotton Cultivation

The variety Andrews was first introduced in this country in 1952, when 100 seeds were secured from the West Indies by the Indian Central Cotton Committee, Bombay and supplied to the Sea-Island Cotton Scheme, functioning in the then composite Madras State. Varietal trials conducted since then at the Agricultural Research Stations, Pattambi and Mangalore as a rain-grown crop on *modan* soils, showed that Andrews was superior to Montserrat, the best variety at that time, in growth, yield, ginning per cent and earliness. It was also found to be much more tolerant to pests and diseases. The average yield at the Agricultural Research Station, Pattambi, during 1955-56, when the seasonal conditions were very favourable, was of the order of 1600 lb. of *kapas* per acre. The ginning per cent was 33. The seed is naked and according to the report of the Director, Cotton Technological Laboratory, Matunga, the oil content is about 20%. The staple length was 1.5 inch and it was found suitable for spinning 70 counts. The lint was valued at Rs. 2,700 per candy on 22-8-1956, which was the price offered for some of the best imported Karnak varieties. Investigations on the agronomic aspects showed that if the crop has to be grown on lateritic soils, which have poor fertility status, and low moisture retention capacity, it was necessary to saturate the soil with as much manure as possible using both organic manures and artificial fertilizers to supply nitrogen, phosphorus and potassium. Preservation of soil moisture and protection of crops against drought were found to be very necessary for successful cultivation of the crop. Since the response was much better on richer soils, like jungle-cleared areas, it was found worthwhile to limit the cultivation of this crop, as far as possible, to fertile soils. Protection of crop against pests and diseases was found to be very essential to maintain the yield levels. Other factors were timely land preparation, and sowing the plant on ridges or mounds to provide sufficient soil to the young seedlings to get a firm hold and provide adequate drainage during the monsoon months. In the difficult tracts receiving heavy rainfall, raising seedlings in the pre-monsoon period and transplanting the same in the monsoon period were also found to be useful in establishing the crop. Due to the difficult terrain of the tract it was found difficult to introduce labour-saving implements for sowing and for later inter-cultivation. The short period available for such operations during the monsoon period and above all the dearth of cattle power were the other handicaps felt in the tract. On many occasions, sufficient time is not left for land preparation due to failure of pre-monsoon rains and later most of the operations will have to be done, almost simultaneously, within a brief period of 2 to 3 weeks when uncontrollable rains are received continuously. Difficulty is also experienced in getting cattle for preparatory cultivation, since the latter are not allowed on the land till it gets sufficiently softened. Further during the sowing season the cultivators will be pre-occupied with the planting of paddy and other food crops and the timely sowing of cotton is often delayed in many areas. Since this cotton is raised in heavy rainfall tracts, weeds take the upper hand by rapid growth and the cultivators will have to take vigilant steps to check the menace. Experiments conducted in this connection have shown that leaf mulching not only controls soil erosion and weeds but also preserves the soil moisture at a later stage of the crop growth, when drought is experienced for a brief period of about a month between August and September. As this cotton is being introduced in areas where cultivators are not familiar with the crop, constant technical advice is necessary to give them confidence. Careful attention will have to be bestowed at the time of picking in order to fetch the best price for the *kapas* in the market. Establishment of ginning factories and proper marketing facilities are vital problems connected with the rapid development of this cotton.

Plan of Working of the Scheme and Progress Made

With the available quantity of 1060 lb. of Andrews cottonseeds, it was programmed to raise 135 acres in the States of Kerala, Mysore and Assam during 1957-58. Despite the adverse seasonal conditions and non-familiarity of the cultivators with this crop, it was possible to secure 18,000 lb. of good seed for raising an area of 2500 acres during 1958-59 in the three States. Information gathered during 1957-58 showed that this crop could be raised, both in the coastal areas of Kerala and Mysore and in non-coastal areas receiving a rainfall of 40 inches and above. Boll opening and quality of lint were found to be uniformly good in spite of differences in soil, climate, and altitude. However, it was observed that the maturation period of the crop was longer in the non-coastal areas by a month. As a result, the growth of the plants was also greater. Increase in size of the bolls and seeds was also noted. As regards yield, wherever the crop was raised under the best conditions, this ranged from 500-1100 lb. of *kapas* per acre. Even on poor soils and despite severe drought during the last year, the yield levels ranged from 150 to 400 lb. of *kapas* per acre.

Marketing

Arrangements were made for marketing of the produce harvested from the States of Kerala and Mysore. In all 36,000 lb. of *kapas* was collected. Great care was exercised to gin the *kapas* at Coimbatore under the technical guidance of the Ginning Supervisor deputed from the Cotton Technological Laboratory, Matunga, Bombay. Arrangements were also made to grade the *kapas*. Finally, from the 36,000 lb. of *kapas* ginned, 24.5 bales of lint and 21,000 lb. of seeds were realised. All the bales were sold in the market, the major portion at Rs. 2,200/- per candy of 784 lb.

Potentialities for the Production of Cottonseed Oil from Andrews Cotton

Assuming that the seasonal conditions of 1958-59 prove favourable for the crop, an overall yield of 500 lb. of *kapas* per acre is expected. This will give a sufficient quantity of seeds for distribution over an area of about 30,000 acres during 1959-60. Thus by the end of the Five-Year period, when 3 lakh of acres are covered, the estimated production of seed per annum would be about 45,000 tons, on the basis of 500 lb. of *kapas* per acre and 33 ginning per cent. The annual requirements of seed for sowing 3 lakh acres would be 1300 tons. Thus a surplus quantity of 43,700 tons would be available for the cottonseed industry every year from this source. Assuming a 20% oil content, the quantity of oil that could be produced every year would be 8,740 tons. Thus by growing this cotton, not only would the country benefit by production of oil but to this extent cultivators also would find a good market for disposal of surplus seeds.

The establishment of composite ginning, pressing and seed-crushing factories in the various growing centres would enthuse the cultivators of the tract to raise Sea-Island Cotton with the definite assurance of a market and to bestow all the attention to the crop so necessary for good yields.

As already stated, the seeds of Andrews cotton are naked. Therefore, the possibilities of exploitation lie only in products like oil, hull, cake, pigment, etc., and not in linters.

Since it is programmed in the Scheme to improve the quality of Andrews cotton by plant-breeding research and increase the yield by agronomic studies, the production of the crop is expected to improve considerably in coming years, when high-yielding, disease and pest-resistant strains are evolved and multiplied, adaptable to the varying soil-climatic complexes obtaining in the different tracts of the three States. While attempting to achieve these objectives there is every possibility of improving the oil content of the seed also. Oil technological research institutions could obtain a large volume of data by analysing samples of seeds from the various experimental plots conducted on the Sea-Island Farms that are being established in the country.

3. THE ROLE OF A BREEDER IN ESTIMATING COTTONSEED PRODUCTION

By
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Cottonseed production is calculated on the basis of lint outturn, and any change-over from one type to another can lead to erroneous deductions. In estimating the seed available for crushing, the sowing requirements and that for use as cattlefeed also needs to be known. In working out statistics for each tract in stepping up production, technologists and plant-breeders will need to collaborate.

Introduction

There has been some controversy in the country about the production of cottonseed and the achievement of targets fixed for the Second Five-Year Plan. The future of the cottonseed crushing industry depends upon accurate estimates of the production of cottonseed in the country and the samples that will be available after meeting the sowing requirements. The role of the cotton breeder in giving a correct estimate is presented in this note particularly with reference to Andhra Pradesh.

Production of Seed

The estimation of production of seed depends upon (i) area sown to cotton, (ii) yield per acre and (iii) ginning per cent of the types cultivated. In Andhra Pradesh the chief cotton-growing areas are:

(*a*) Westerns and Mungari of Kurnool, Cuddapah and Anantapur Districts.
(*b*) Northerns of the Nandyal valley in Kurnool District.
(*c*) Cocanadas and Chinnapathi of Coastal District.
(*d*) Gaorani and Parbhani American of Adilabad and Nizamabad Districts, and
(*e*) Oomras of Karimnagar and adjacent areas.

The details of area and production of lint in bales (of 392 lb. each) are furnished for the several tracts in Table I. It will be seen that a total area of 10.1 lakhs of acres are

TABLE I.

Area and Production of Cotton in Andhra Pradesh

(Figures mostly derived from the final forecast of 1957-59 season)

No.	Trade group	Area in acres (X hundred)	Production in bales (X hundred)
1.	Westerns and Mungari	6,115	840
2.	White and Red Northerns.	750	80
3.	Gaorani and Parbhani American.	1,404	181
4.	Cocanadas and Chinnapathi.	891	133
5.	Oomras, Kumptar, etc.	905	104
	Total ...	10,065	1,338

under the crop from which 1.3 lakhs of bales are produced. These figures do not enable one to work out the yield of seed directly as the same depends upon the area under each variety, its yield and ginning per cent and the extent of its spread in a tract. The maximum area and production are from the Westerns and Mungari tract which is responsible for about 60% in the State. The yield per acre is again dependent upon the rainfall, soil and whether irrigated or rainfed. Most of the cottons of the State are rainfed. The highest yield per acre is obtained in Cocanadas tract where the average rainfall is about 35 inches while the lowest yields are recorded in the Westerns tract where the rainfall is about 20 inches.

The ginning per cent similarly varies widely, ranging from 24 of Northerns to 35 of Mungari and Oomras cottons. This means that the percentage of seed in cotton varies from 65 to 76 in the various tracts. Based on the ginning per cent of the various types and the area sown to cotton, an estimate of production has been made according to which annually about 99,320 tons of cottonseed is produced at present in the State. As the area of cotton under irrigation is developed under the Tungabhadra Project, etc., the production of seed will increase very much. The production will vary depending upon the varieties released from time to time. For instance, in the Northerns tract the strain N. 14 which occupies about 50,000 acres has a lint outturn of 24 per cent and is likely to be replaced by a type with 30 per cent of lint outturn. The outturn of seed per acre will therefore fall from 150 lb. to 140 lb. by this change in the strain. Taking the area of spread of this strain alone into consideration there will be a reduction of 5,00,000 lbs., or 223 tons of cottonseed in one tract itself.

Coming to the quantity of seed that would be available for the crushing industry the following points require to be taken into consideration:

(i) The sowing requirements of seeds in the several tracts, and

(ii) The quantity of seed fed to cattle.

Sowing Requirements of Seeds

The sowing requirements also vary from tract to tract. In the Westerns tract where droughty conditions exist, a lower seed rate is adopted than in the other tracts. A higher seed rate of about 20 lb., per acre is adopted in the case of Mungari areas to guard against ravages of insect pests. The seed rate is higher for large-seeded American (Cambodia) varieties than for *desis* (cottons of Indian origin). It is estimated that annually about 6,000 tons of seed are required for sowing purposes.

Cottonseed as Cattlefeed

In some of the non-cotton growing areas of the State there is even a prejudice against feeding cottonseed as cattlefeed. Large areas in these regions are expected to come under the Nagarjunasagar and Nizamsagar projects when the seed production is expected to be trebled as a result of irrigation of the crop. In the cotton-growing districts of Kurnool, Cuddapah and Anantapur cottonseed is generally fed to cattle, the prejudice however being against fuzzy American cottonseed, although baseless (Lander and Dharmani[2,3]) Here too extensive areas of cotton are being brought under the Tungabhadra Project Ayacut where there is a programmed campaign in progress for increasing the area under Laxmi, an American type, and for stepping up the present production. Such a step would also enhance the yields of cottonseed, consequent on increased seed cotton yields, which will be entirely available for crushing purposes, barring the seed requirements for sowing. The cottonseed oil industry will have to be backed by intensive propaganda among farmers to feed cake in place of whole cottonseed to their cattle.

Lander and Dharmani[1] had suggested that feeding cottonseed cake is advantageous and economical compared to feeding of cottonseed. Sirur[4] also argues that the required energy for an animal (believed to be got through fat content of the diet) can as well be had from the protein and cellulose contents of the cake. These results require to be popularised with the cultivators. Such a propaganda releases large quantities of seed for crushing purposes without affecting the cattlefeed requirements.

Conclusions

There is controversy in certain quarters over the production of cottonseed in the country and the ways and means of estimation of the same. The estimation of production is dependent on the area sown to cotton, the yields and the ginning percentage of types. It is only when the outturn of seed to *kapas* is exactly known that a correct estimate of seed production in the country can be had. The breeders who are introducing improved types from time to time will have to be consulted in arriving at a correct estimate, otherwise the estimates are likely to be unrealistic. The availability of surplus seed for crushing is similarly based on the requirements of cottonseed for sowing purposes, and as cattlefeed. A correct assessment of all these factors is essential in fixing targets for stepping up production of cottonseed. Detailed statistics will have to be worked out for each tract and a plant breeder's role in this direction is all the more enhanced. It is therefore suggested that a co-ordinated body of technologists and cotton research workers be set up for the purpose.

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4. PROXIMATE COMPOSITION OF SOME HYDERABAD AND BOMBAY COTTONSEEDS

By

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Proximate analysis of 16 Indian cottonseeds derived from Bombay and Hyderabad showed the existence of two distinct types, the desi type low in seed index (average 5.72), linter content (3.8%) and oil content (19.6% on dry delinted seed), and the American varieties high in these characteristics (9.01, 11.6 and 21.7 respectively) and closer to the U.S.A. averages (11.11, 13.8 and 22.2). Oil contents on a whole-seed basis were very similar at 17.4, 18.0 and 17.6% respectively for the three categories. The difference in these linter contents with data later published may be occasioned by inefficient ginning.

Introduction

Till about 1940 cottonseeds had been classified and bred exclusively according to their fibre characteristics, such as colour, staple length, ginning outturn and warp count for which suitable. The growing interest in cottonseed as an oilseed has led to systematic examination of the varieties already in existence in the country for their suitability as sources of linters and of oil.

The literature on the proximate analyses of Indian cottonseeds before 1953 is scanty. Leather[1] analysed 74 samples of cottonseeds derived from the provinces of Madras and Bombay, and the United and Central Provinces, and obtained averages of 17.41, 17.66, 19.65 and 19.8% for oil on the whole seed respectively; he also recorded that American, Egyptian and Indian seeds had different seed weights, the respective weights per 100 seeds (the modern 'seed index') being 12-18, 10-11, and 5-7 grams. In 1944 Athawale[2] divided the 88 cottonseed samples he had examined into four classes depending on oil percentages; three-quarters of the seeds, which were derived from ten provinces, fell in the range 17.5-22.5%. Ranges for moisture, hull, kernel and lint(er) contents were all given, but no correlation attempted. It is significant in the light of the present work that the lint ranged from 0.02 to 3.25% and hence the seeds were probably all of Indian origin. The interesting suggestion was made that low oil-content seeds could be used for cattle feeding and only seeds of high oil-content for oil milling. In 1948, Afzal[3] in a general article gave some data; cottonseeds were classified in three categories — of low fuzz (*desi*), of low fuzz (American, including varieties like 4F and LSS grown in the Punjab), and of high fuzz (American e.g. 289 F); percentages quoted for the three categories for moisture were 6.8, 6.7 and 6.3, and for oil 17.6, 20.7 and 18.8 (presumably on a whole-seed basis). Figures for protein, ash and fibre were also given.

In 1953, Harwalkar, Achaya and Saletore[4] published the results of proximate analysis of some Hyderabad and Bombay cottonseeds and these, together with some later unpublished figures, are summarised in Table I.

TABLE I

Proximate Analyses of Hyderabad and Bombay Cottonseeds.[4]

No.	Place of Origin	Variety	Year	Seed index	Moisture %	In dry seeds		In dry, delinted seeds			In whole Seeds	In meal	
						Linters %	Ash %	Hull %	Kernel %	Oil %	Oil %	Moisture %	N %
	Desi varieties												
1.	Nanded (Hyderabad)	Gaorani 6	1950	5.18	10.6	3.7	3.5	43.2	56.8	20.3	18.0	4.9	2.6
			1952	5.37	6.8	4.1	...	45.0	55.0	20.4	18.0	2.5	3.0
2.	Raichur ,,	R. K. 19	1950	5.71	9.6	5.4	3.7	46.0	54.0	17.5	15.2	6.7	2.5
3.	Kopal ,,	Jayawant	1950	5.63	10.0	3.1	2.8	46.7	53.3	18.7	16.7	6.3	2.8
			1952	6.47	9.5	3.4	...	46.4	53.6	19.9	17.7	3.8	3.0
4.	Latur ,,	G. 12F. 2	1950	5.63	9.1	3.8	3.6	40.5	59.5	20.2	17.9	5.8	3.1
			1952	5.84	8.7	3.1	...	43.4	56.6	20.3	18.1	4.3	3.1
5.	Hubli (Bombay)	Jayadhar	1951	...	9.3	3.6	...	47.0	53.0	19.4	17.0	...	...
6.	Bijapur (Bombay)	Jarilla	1952	5.95	8.5	3.5	...	41.8	58.2	19.8	17.6	...	...
		Averages:		5.72	9.2	3.8	3 4	44.4	55.6	19.6	17.4	4.9	2.9
	American varieties												
1.	Adilabad (Hyderabad)	Parbhani-American 1	1950	9.06	12.1	13.2	3.1	43.3	56.7	20.5	16.4	4.5	2.9
			1952	10.79	9.3	13.5	...	41.0	59.0	21.8	17.4	3.1	2.9
2.	Hubli (Bombay)	Laxmi	1951	..	9.0	12.3	...	37.6	62.4	22.7	18.3	...	...
3.	Bijapur (Bombay)	,,	1952	7.78	7.5	11.4	...	44.7	55.3	21.2	17.9	...	...
4.	Bijapur (Bombay)	CO 4 or Rajapalyam	1952	8.06	7.4	9.9	...	41.5	58.5	22.8	19.4	...	...
5.	Tirupur (Madras)	Cambodia	1952	9.00	8.3	11.0	...	39.0	61.0	20.5	17.6	...	...
6.	Gokak	,,	1952	9.40	8.2	9.8	...	44.3	55.7	22.4	19.0	...	...
		Averages:		9.01	8.8	11.6	3.1	41.6	58.4	21.7	18.0	...	...
	Average for the U. S. A. 5			11.11	7.6	13.8	4.7	44.4	55.6	22.2	17.6	...	...

Conclusions

1. The moisture content of cottonseed is extremely dependent upon the humidity and hence is largely conditioned by the season of analysis. The 1950 seeds were analysed during the humid June-August season of that year and the 1952 samples during the drier post-August period, and this is reflected in the moisture content.

2. There appear to be two distinct types of cottonseed. The *desi* type is characterised by low residual linter and oil contents and low seeds weight, and the other type, to which belong seeds of American origin grown in India, are high in all these characteristics, and much closer to the averages of these characteristics shown by seeds grown in America.[5] Though the oil contents on a *dry, delinted* basis appear to vary, it is interesting to note that when reduced to a *whole-seed* basis, the percentages even out considerably, and the averages for oil content come to 17.4, 18.0 and 17.6% respectively for *desi*, American-type and United States cottonseeds.

3. During the five years since this work was published, Murti[6] and co-workers have shown by extensive data that the distinction between *desi* and American-type seeds in regard to linter content is by no means as clear-cut as our data would suggest, and that there is a good deal of overlapping at the 5-7% linter level. True linters or fuzz are short fibres morphologically distinct from residual lint or cotton; but if the gins are not efficient, some cotton may be left on the seed and will raise the apparent linter content in later analytical estimations. This is confirmed by the widely varying content of apparent linters in the same variety of cottonseed obtained from different gins shown in the data of Murti.[6] Hence, it may be considered still possible that *desi* and American-type seed differ fundamentally in their content of true linters.

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5. OIL CONTENT AND LINTER CONTENT OF DIFFERENT INDIAN COTTONSEED VARIETIES

By

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Of 120 cottonseeds analysed, the hirsutum and barbadense varieties had high contents of oil (19-20%) and the Garohills (arboreums) from Assam a content of only 10-12%. Oil content calculated on kernel weight was the same for both hirsutum and barbadense. Laboratory linter contents agreed with plant delinting returns, but about 3% could not be cut in the later. Garohills showed a high percentage linter content. The total quantity of cottonseeds available is calculated at 15 lakh tons, with a steady rise in the production of long-stapled American-type cotton.

Introduction

Cottonseed has been used in this country as cattle-feed from very early times but its industrial utilization has received serious attention only recently. The main products of the cottonseed are oil, cake or meal, linters and hulls and all these products are of high industrial value. Cottonseed oil can be used for edible purposes after hydrogenation, in the manufacture of soaps, paints and varnishes, in the toilet and leather industries and as a lubricant. Linters provide high-grade cellulose suitable for the manufacture of rayons, explosive materials, lacquers, etc. The indigenous vanaspati and soap industries which were hitherto depending on other sources have started using cottonseed oil and many cottonseed crushing factories are being started. Similarly, the production and utilization of linters are being planned. The Government of India on their part are giving all encouragement to the promoters of the cottonseed industry and have also fostered many research schemes in different institutions in this connection. The Indian Central Cotton Committee has undertaken investigations on the linter output of different varieties of cottonseed and also on their oil content with a view to growing cotton varieties with a higher oil yield without sacrificing the lint qualities. Some of the results of these investigations are presented and discussed in this paper.

The cottonseed samples belonging to different varieties of cotton strains were obtained from different cotton breeding stations all over India.

The oil content of these samples was determined by the solvent-extraction method[1] which was adopted with some modifications. A sample of 5-10 gms.. of seed was accurately weighed and heated at 130°C in a draught oven for two hours and then crushed. The crushed seed was placed in a thimble and extracted in a soxhlet apparatus for six hours with the fraction (65-68°B.P.) of the solvent obtained from Messrs. Burmah Shell Oil Co. The oil extract, after filtering in a sintered glass crucible, was dried to a constant weight. The moisture content of the seed was determined separately by heating the seed at 100°C for sixteen hours and the oil content was expressed on 10 per cent moisture basis.

TABLE I

Summary of the Oil Contents of Cottonseeds Belonging to Different Gossypium Species

(Oil content on 10 per cent. moisture basis)

Species	Number of samples analysed	Average oil percentage		Range of oil percentage		Samples having oil content above 20 per cent.		Samples having oil content between 17–20 per cent.		Samples having oil content between 15–17 per cent.		Samples having oil content below 15 per cent.	
		1956	1957	1956	1957	1956	1957	1956	1957	1956	1957	1956	1957
G. hirsutum	47	18.90	19.06	13.92 to 22.13	15.08 to 23.08	12	12	31	31	3	4	1	...
G. herbaceum	27	17.42	16.32	12.58 to 19.83	12.64 to 19.17	...	...	20	8	2	12	5	7
G. arboreum	46	17.15	18.34	14.80 to 19.98	16.32 to 21.29	...	4	25	35	20	7	2	...
G. arboreum Garohill-type	2 & 3	12.52	... 12.03	11.28 to 13.77	... 10.97 to 13.05	...	...	...	...	...	...	2	3
G. barbadense	2	19.7	...	18.94 to 20.45	...	1	...	1	...	...	...	...	...

TABLE II

Oil Content of 320 F and LL 54 Cottonseeds Grown With Different Irrigations and With Different Doses of Nitrogen Applied

Serial No.	Number of irrigations	Oil content for 320 F, per cent.	Oil content for LL 54, per cent.	Doses of Nitrogen/acre, lb.	Oil content 320 F and LL 54, per cent.	
1.	3	19.73	18.46	0	20.12	19.12
2.	5	20.17	19.01	40	19.65	18.84
3.	7	20.08	18.82	80	19.98	18.43
4.	...	...	...	120	20.20	18.65

TABLE III

Linter, Oil, Kernel and Hull Contents of G. hirsutum Seeds

Serial No.	Variety	On 10% moisture basis		Kernel content (%)	Hull content (%)
		Oil content (%)	Linter content (%)		
1.	320 F	23.08	3.79	59.75	36.46
2.	M. C. U. 1	21.74	11.59	57.50	30.86
3.	CO. 4	21.06	10.71	56.10	33.19
4.	01545 C	19.94	9.96	56.35	33.69
5.	M. C. U. 1	19.30	8.95	55.15	35.90
6.	9030 G	19.09	11.42	54.80	33.78
7.	0394	18.93	10.61	53.75	35.64
8.	P. A. 1	18.15	16.54	52.00	31.46
9.	M. C. U. 2	17.87	9.12	55.30	35.58
10.	Laxmi	17.80	12.78	53.15	34.07
11.	Indore 2	17.49	12.70	51.00	36.30
12.	216 F	17.43	15.25	49.50	35.25
13.	C. T. I. 4-27	16.52	10.78	49.30	39.92
14.	4057	15.08	11.75	42.80	45.45

TABLE IV

Linter, Oil, Kernel and Hull Contents of G. herbaceum Seeds

Serial No.	Variety	On 10% moisture basis Oil content (%)	 Kernel content (%)	Kernel content (%)	Hull content (%)
1.	1027 A. L. F	18.34	4.85	52.20	42.95
2.	2087 W. R.	18.35	3.02	54.05	42.93
3.	Suyog	18.08	3.61	49.40	46.99
4.	Digvijay	16.76	2.64	45.50	51.86
5.	669 — B	16.22	5.31	53.13	41.54
6.	Kalyan	15.94	5.54	49.05	45.41
7.	280 — 1	15.89	7.33	48.95	43.72
8.	Vijay	15.18	2.76	52.85	44.39
9.	Jayadhar	14.37	2.59	48.20	49.21
10.	B. C. 1	14.30	3.78	50.55	45.67
11.	596. B	13.46	4.76	48.50	46.74
12.	KFT-12-2-5	12.64	2.22	49.10	48.77

TABLE V

Linter, Oil, Kernel and Hull Contents of G. arboreum

Sr. No.	Variety	On 10% moisture basis Oil content (%)	 Linter content (%)	Kernel content (%)	Hull content (%)
1.	W 81 S. B	20.47	4.23	55.24	40.52
2.	Virnar	20.12	4.16	50.75	45.09
3.	B. C. 2—28	19.85	3.94	56.85	39.21
4.	Y. 1. O. B.	19.56	4.64	53.70	41.66
5.	Gaorani 12	18.81	3.80	54.65	41.55
6.	Jarila	18.53	3.58	51.70	44.72
7.	Cocanadas 2	18.20	5.81	51.75	42.44
8.	Cocanadas 1	17.89	4.92	49.80	45.28
9.	Bhoj	17.65	4.52	49.50	45.98
10.	K. 2.	16.48	3.98	49.80	46.22
11.	K. 5.	16.32	5.38	48.70	45.95
12.	C. J. 73	17.53	7.55	52.40	40.05
	Garohill Type				
1.	G. 135-49	13.05	9.59	40.20	50.21
2.	G. 27-51	12.04	10.12	40.40	49.48
3.	G. 54-1	10.97	9.53	38.90	51.57

TABLE VI

Analysis of the Values Given in Tables III, IV & V According to Species

Species	Total number of samples analysed	Average content of				
		Oil (%)	Linter (%)	Kernel (%)	Hull (%)	Oil in kernel (%)
G. hirsutum	14	18.82	11.13	53.32	35.55	35.29
G. herbaceum	12	15.80	4.03	50.12	45.85	31.53
G. arboreum	12	18.26	4.71	52.07	43.22	35.06
Garohills	3	12.02	9.75	39.80	50.45	30.20

TABLE VII

Experiments Conducted at Navsari by Mill-run

No.	Cottonseed	Species	Linter percentage on weight of cotton seeds
1.	Mysore American M.A.V.	*G. hirsutum*	7.2
2.	216 F.	do	8.3
3.	Cambodia CO 2.	do	10.1
4.	Buri 107	do	6.2
5.	Parbhani American	do	8.7
6.	Suyog	*G. herbaceum*	1.4
7.	Jarila (Jalgaon)	*G. arboreum*	1.1
8.	Indore Malvi	do	1.1
9.	Mollisoni 39	do	1.1

TABLE VIII

Experiments Conducted at Hubli by First-cut and Second-cut

No.	Cottonseed	Species	Linter percentage on weight of cottonseed		
			First-cut	Second-cut	Total
1.	Laxmi	*G. hirsutum*	2.8	5.6	8.4
2.	Mysore American M.A.V.	do	4.5	3.3	7.8
3.	Cambodia CO 2	do	4.1	3.9	8.0
4.	Madras Uganda 1	do	4.3	3.3	7.6
5.	M.P. Cambodia	do	2.6	3.9	6.5
6.	Mewar American	do	2.2	3.6	5.8
7.	Parbhani American	do	3.9	5.4	9.3

TABLE IX

The total Area and Production of Cotton in India for Three Seasons with the Percentage Production of Desi and American-type Cottons

Year	Area (thousand acres)	Production (thousand bales of 392 pounds each)	Percentage production of *desi* cottons	Percentage production of American-type cottons
1954-55	18,238	4,271	75	25
1955-56	19,978	4,001	73	27
1956-57	19,843	4,723	71	29

About 120 cottonseed samples of different varieties of cotton grown in different localities were tested for their oil content successively for two years. Table I gives the summary of results of the oil content of different species.

It can be seen from the results that the *hirsutum* varieties, which usually give long-staple lint, have also yielded, in general, a higher percentage of oil (about 19 per cent). Although the *arboreums* have given a low value for the 1956 season (about 17 per cent), they have shown a fairly high oil content for the 1957 season (about 18.5 per cent). However, the *arboreums* grown in Assam belonging to the Garohill-type, which possess short-staple lint, have shown a very low percentage of oil (10—12 per cent). The *herbaceums* have yielded a medium percentage of oil (averaging about 17 per cent). The *barbadense* seeds which are practically naked have given high percentage of oil (about 19-20 per cent). The oil actually available by crushing in the industry will be about 3 per cent. lower than the values obtained in the laboratory by the solvent-extraction method.

Some experiments were done to ascertain the effect on the oil content of the seed of irrigation and the dose of nitrogen applied during the growth of the plants. Table II gives the oil contents of two varieties of cottonseeds grown with a different number of irrigations and with varying doses of nitrogen applied. The results indicate that no appreciable difference in the oil content is obtained due to these agronomical treatments.

The linter content of some of the seeds of different species was determined[1] in the laboratory by gassing the seeds in hydrochloric acid fumes in a fuming oven and dusting out all the fuzz from the seeds. The kernel weight and the hull weight of the seed samples were determined by carefully cutting out and separating the kernel and the hull from the seeds of one gm. of each sample. Tables III, IV and V show the oil and the linter values and also the hull and the kernel weights of seeds belonging to *hirsutums, herbaceums* and *arboreums* respectively. Table VI gives the summary of the above values on the basis of different species.

Some delinting experiments were also carried out on a large scale at the Indian Cotton Oil Mills, Navsari and the Sundatta Cottonseed Utilization Co., Hubli with one ton of seeds of different varieties obtained from various parts of India. Table VII and VIII give the values of linter percentage of different cottonseed samples obtained from roller ginning factories.

The values for linter content as determined in the laboratory are slightly higher than those obtained in large-scale trials, but there is good agreement between the two with regard to the availability of linters in different species. It may be assumed that about 3 per cent less of linters than the laboratory values could be realised under practical conditions, as in the case of the oil also. In large-scale processing, the *desi* varieties yield about 1-2 per cent. of linters and the American varieties about 8-9 per cent.

It is interesting to note that *desi* seeds of the Garohill-type give high percentages of linters though yielding very low percentages of oil.

The oil contents of all the varieties tested show a relationship with kernel weight and the results indicate that the oil content calculated on kernel weight of both *arboreums* and *hirsutums* is almost the same.

Table IX gives the total area and production of cotton in India for three seasons (1954-55, 1955-56 and 1956-57)[2] together with the percentage production of *desi* and American-type cottons. It can be seen that the average production of cotton for three years is about 4,330 thousand bales of 392 lbs. each; assuming the seed weight to be approximately double the lint weight, the total quantity of cottonseeds available per annum on the average would be about 15 lakh tons. The total oil available from the above quantity of seeds would be approximately 2.25 lakh tons on a 15 per cent. basis.

The cake or meal obtained after mechanical crushing would still contain 6-7 per cent its weight of oil which is considered to be an adequate quantity for animal feeding. This oil can be completely extracted with solvents but this would leave the cake deficient in oil for cattle feeding. India being mainly an agricultural country, due importance must be given to the feeding of the large number of animals. Therefore, a sufficient amount of the cake required for the cattle population of India should be reserved and the excess may be processed with solvents for complete recovery of oil.

As *desi* seeds do not possess any appreciable quantity of linters, they may be directly crushed for oil. It can be seen from Table IX that there is a steady rise in production of long-stapled American-type cotton. The total amount of linters only from American-type seeds (*hirsutums*) for the 1956-57 season would be about 38,000 tons on an 8 per cent. basis.

Acknowledgment

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6. VARIETAL CHARACTERISTICS OF INDIAN COTTONSEED

By

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1. Data on the varietal characteristics, viz., oil content, residual lint content, size of the seed and seed index, for 540 representative samples of major varieties of Indian cottonseed produced from 1951 to 1957 are presented together with the production figures of each variety and their ginning percentage. The species of each variety and the regions where they are grown are also given.

2. The variations in residual lint and oil contents in the samples, as affected by the prevalent condition of ginning and their bearing on cleaning, delinting and crushing of commercial cottonseeds, are discussed with a view to greater utilization of cottonseed for crushing.

3. The factors responsible for wide variations in the fuzz content of the same variety of seed obtained from different regions are discussed.

4. The advantages of delinting cottonseed at the ginning factories instead of doing it at the seed crushing mills are discussed.

5. The need for evolving cottonseed varieties of high oil content is stressed.

Introduction

India ranks third among world cottonseed-producing countries, next to the U.S.A., and the Soviet Union.[1] The production of cottonseed for 1956-57 (partially revised estimates) and 1957-58 (final estimates) are 1,657 and 1,664 thousand tons respectively[2] and the same is targeted to reach 2,000 thousand tons by the end of the Second Five-Year Plan. While cottonseed plays an important agro-industrial role in the economy of the U.S.A. and some other cotton-producing countries, in India till recently cottonseed was given an unimportant role, being utilized almost exclusively for the purposes of sowing and cattle-feed. Since the Second World War, the potential oil-wealth of cottonseed has been fully realised and efforts are being made to exploit the same by crushing for oil, adopting modern equipment. At present, only about 5-7% of the cottonseed produced is being crushed and by the end of the Second Five-Year Plan, 20% of the seed produced is recommended to be crushed,[3] a figure which is not at all likely to be attained.

There are two problems in the development of cottonseed crushing industry, as in any other industry—first, that of proper selection and availability of suitable raw material, and second, of suitable plant and equipment. This paper deals with the former aspect. Data are given regarding some of the essential varietal characteristics, important from the standpoint of pre-treatment and crushing of the major varieties of cottonseed produced in all the important cotton-growing States of India. The trade names and the species of these varieties, ginning percentage, production, and geographical regions are also given so as to give an idea of their potentialities with respect to availability and adoption for processing.

Experimental

Research work on cottonseed was undertaken at this Institute since 1952, to obtain data on the composition and characteristics of Indian cottonseed and its pre-treatment and crushing.

In all, about 540 representative samples of major varieties of cottonseed produced during the seasons 1951-52 to 1956-57 were analysed for their moisture content, oil content, residual lint, F.F.A. of oil in the seed, size of the delinted seed and seed index (wt. in gms. of 100 seeds). A.O.C.S. Methods were adopted for the determination of moisture, oil and residual lint contents. Data on 230 samples have already been published[4,5,6] and data[15] on the remaining 310 samples will be published shortly. This is the only comprehensive data worked out systematically on all the major varieties of Indian cottonseed obtained from different harvesting seasons and from all the important cotton-growing regions of the country, though some data by others has also been published [7,11] prior and subsequent to this work. Data on the oil content, residual lint content (calculated on a moisture-free basis), size and seed index of Indian cottonseeds summarised from the work done at this Institute are presented in Table 1.

Discussion of Results

Any variety of cottonseed may be characterised in different ways. It may be classified according to the staple length of the lint produced by the seed, viz., long, medium or short, this classification would be of use to the textile industry. Cottonseed can also be classified under one of the four species to which all varieties of Indian cottonseed belong, *Gossypium hirsutum, G. herbaceum, G. arboreum* and *G. barbadense,* leaving aside other secondary racial differences like *wightianum, indicum* and *bangalensis* occurring among them and other variations due to hybridization. This classification is of interest to the plant geneticist and agronomist. A broader classification would be into American and *desi,* and the latter again into improved *desi* and indigenous *desi.* This offers a rough but ready reference both to agriculturists and cottonseed processers. Yet another classification would be according to the geographical region in which the cottonseed is produced. The classification of the different varieties of cottonseed on the basis of their composition would be in order and illuminating if a large volume of analytical data, covering thousands of genuine samples, on the composition of all varieties of cottonseed of known antecedents, produced in all parts of the country under known classified climatic and soil conditions from year to year, were worked out by a close and systematic liaison between the Cotton Extension Research Stations, Agricultural Departments, Geological and Meteorological Departments and Technological Laboratories. Till such time as this is done, the most convenient and useful method of classification of cottonseed would be to start from the trade name of the variety grown in different parts of the country and characterise it by its quantitative features, as has been done in this paper.

Commercial cottonseeds, used as an oleaginous raw material or as seed for planting purposes, have been "ginned" of their staple cotton. In that form the seed comprises residual lint, hulls and meats. Hence any data on oil and residual lint contents will be of great use for milling and delinting of cottonseed. Data on size and seed index will be important from the standpoint of selecting suitable seed-cleaning equipment and necessary screens. While the moisture content of the seed and F.F.A. of seed oil are also equally important from the standpoint of utilization of cottonseed for crushing, they are omitted from the data presented in this paper since they are highly variable constituents varying not only from sample to sample of the same variety but also in the same sample at different times.

From the data presented in Table I, it is seen that C-Indore 1, LSS, 320 F and Buri varieties among American-type seed exhibit very high oil contents, closely followed by MU 1 and MCU, Lakshmi, Parbhani American, G1, H14, Indore-2, M.A. and Raj varieties. Among the *desi* varieties, those of Andhra (Chinnapathi, Cocanadas, Desavali, Umri), Virnar, Gaoranis, Malvi, Vijay, Jarila, Rajasthan *Desi*, H420, Pratap and 2204 contain high oil contents.

As for residual lint contents, Raj, Parbhani American, 134-C02-M, H14, M.A. and Cambodia varieties generally have the highest among American-type seed. Among *desi*-type seed, Mathio, Suyog-Surti, Uppam and Tinnies, 35/1 and 1027 ALF are high in their residual lint contents. Varieties low in residual lint include Vijalpa, Hingari, Jayadhar-Jaywant, Vijay, N14, Gaoranis, C520, 2204 (Daulat) and Bokda among *desi*-type seed, and C-Indore 1, LSS, 320F Buri, G1 and Indore 2 among American-type seed. It is interesting to note from the data in Table 1 that American varieties high in oil content are relatively low in residual lint content. But it has also to be borne in mind that the linters or fuzz content of commercial cottonseed is a highly-variable constituent and appears to be largely a function of the efficiency of the gins used. The Ginning Industry in India, as shown by the survey[12] conducted by the Indian Central Cotton Committee, is very inefficient. Some of the gins are reported to be a century old and 35% of the factories have gins more than 50 years old. The Survey further recommends that these are obsolete and have to be replaced, as they are uneconomical and inefficient. This is reflected in the observation that the same variety of seed obtained from different localities has varying residual lint contents. Other factors such as variety, species and environment of growth also contribute to the wide variations in the residual lint contents of the same variety of cottonseed.

The shape and structure of cottonseed is such that it presents certain problems both in ginning and in delinting. It is reported[13] that the strength of attachment of the fibre to the seed is higher at the micropylar region and in some varieties it is lower at the chalazal end. The power consumed in ginning was found to be very much more than the actual work to be done to pull out the fibres from the seed; there was a good association between the power consumed and the work required to be done, though this was partly modified by the fuzziness of the seed. The strength of attachment of the fibre was also found to vary with the relative humidity of the atmosphere. It is reported[13] that there are few fibres in the micropylar end and more fibres in the other regions of the seed and that the former require a much higher work to be done to be pulled out than the others. Thus, neither ginning of seed-cotton nor delinting of cottonseed can be uniform with such an unequal distribution of fuzz on the surface of the seed requiring unequal power to pull them out. It has also been shown[14] that the work done in pulling out fibres from the seed was different for different manurial treatments received by the soil during the growth of the cotton plant. It has also been observed in the course of pilot-plant work that seeds of the various varieties were unevenly delinted at different parts.

The staple length of the lint on the seed might have some effect on the residual lint content of the seed. Thus it will be seen from our data that the residual lint contents of the varieties of cottonseed increase in the order of staple length: short, medium and long.

TABLE

Cottonseed Species, Varietal Characteristics,

(Note:—Figures in brackets indicate the number of samples analysed for each characteristic.

S. No.	Trade name of the variety	Species to which the variety belongs	Oil content Per cent.		Residual Lint Per cent		Size of the seed	
							Minimum	
			Range	Average	Range	Average	Range	Average
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Gossypium						
1.	Madras Uganda (including Cambodia Uganda)	Hirsutum	16.30-24.30	19.90 (47)	6.66-17.10	11.33 (44)	5.5-8.8	7.6 (35)
2.	Lakshmi	Hirsutum	16.44-23.93	20.36 (45)	7.60-14.44	11.50 (45)	5.8-9.8	7.1 (38)
3.	*Desi* varieties of Andhra Pradesh including Cocanadas, Desavali, Umri, Chinnapatti	Arboreum	16.35-27.11	19.56 (37)	3.60-11.44	6.54 (35)	4.4-8.0	5.85 (28)
4.	M. A. variety	Hirsutum	16.80-24.12	20.06 (26)	7.87-17.40	12.20 (26)	5.1-9.0	7.5 (26)
5.	Cambodia	Hirsutum	16.93-22.56	19.60 (25)	8.80-17.34	12.00 (24)	5.6-9.6	7.1 (21)
6.	216 F	Hirsutum	14.64-22.58	19.80 (22)	5.11-17.88	11.70 (22)	5.1-9.0	6.9 (22)
7.	Vijalpa (2087)	Herbaceum	15.50-25.60	18.56 (22)	1.19-8.36	4.48 (21)	5.4-7.2	6.5 (21)
8.	Hingari or H 1 or Westerns or Farm	Herbaceum	15.50-22.58	18.92 (21)	1.11-9.83	3.93 (19)	4.3-6.4	5.5 (12)
9.	Virnar including 197–3	Arboreum	15.82-22.26	19.34 (20)	1.20-6.50	5.24 (20)	5.1-6.5	5.8 (20)
10.	Buri	Hirsutum	19.82-23.75	21.49 (19)	5.40-15.10	8.93 (19)	5.1-8.2	7.0 (19)
11.	Karunganni	Arboreum	14.40-20.91	18.04 (17)	2.44-11.22	7.78 (15)	5.2-7.3	5.9 (13)
12.	Jayadhar-Jayawant varieties	Herbaceum	13.80-21.00	17.51 (17)	1.44-6.67	3.54 (17)	4.3-6.4	5.5 (17)
13.	Gaorani 12	Arboreum	16.70-26.00	19.84 (15)	2.56-8.48	5.13 (15)	4.6-6.7	5.7 (14)
14.	Punjab *Desi*	Arboreum	17.78-23.61	21.03 (15)	2.84-10.11	6.50 (15)	4.5-6.2	5.4 (15)
15.	Malvi 9 including Gwalior 16, Bhoj, etc.	Arboreum	16.44-22.24	19.90 (15)	3.40-13.90	6.50 (15)	5.3-8.0	6.1 (15)

-1.

inning Percentage, Production and Places of Cultivation

Ginning percentage taken as 33 1/3% where actual figures are not available.)

in mms.

Maximum		Seed Index (weight of 100 seeds in gms.)		Ginning percentage	Production of the seed ('000 tons)	Geographical tract where the variety is grown.
Range (10)	Average (11)	Range (12)	Average (13)	(14)	(15)	(16)
.1-10.5	9.8 (35)	7.0-10.9	8.6 (29)	32.0/34.0	86.54-94.10	Tirunelveli, Madurai, Coimbatore, Salem, Ramnad and South Arcot Districts of Madras.
7-11.0	9.1 (38)	4.7-9.2	7.4 (22)	34.4	39.71	Cuddapah and Kurnool Districts of Andhra Pradesh and Bellary, Raichur, Bijapur, Dharwar and Davanagere Districts of Mysore.
4-11.6	7.4 (28)	3.9-12.6	5.6 (17)	25.0-30.0	9.39-12.08	12 Districts of former Andhra State.
1-11.7	9.9 (26)	7.3-8.9	8.2 (10)	35.0	49.73	Mysore, Davanagere, Chikmagalur Mandya, Hassan and Bellary Districts of Mysore.
.8-10.8	9.7 (21)	8.2-9.7	8.7 (7)	32.0	Included under Madras Uganda and Buri	Coimbatore, Salem, Madurai, South Arcot, Ramnad Districts of Madras.
.9-11.2	9.4 (22)	6.2-9.1	7.5 (8)	33.4	Included under Punjab American	Rajasthan, Punjab and U. P. States.
6.9-8.0	7.6 (21)	6.1-6.7	6.4 (14)	36.0	—	Surat, Broach, West Khandesh, and Ahmedabad Districts of Gujerat.
6.8-8.0	7.3 (12)	4.5-6.1	5.0 (10)	30.5	14.76	Cuddapah, Kurnool and Anantapur Districts of Andhra Pradesh and Bellary District of Mysore.
7.0-9.0	7.4 (20)	4.5-5.4	5.1 (6)	39.8	213.9-247.2	Madhya Pradesh, Bombay and Rajasthan.
.8-10.9	9.1 (19)	7.2-9.2	8.3 (9)	32.0/34.0	27.86-30.50	Districts of Madhya Pradesh.
6.5-9.8	7.2 (13)	4.6-6.0	5.2 (10)	30.0/32.0	48.73-53.51	Coimbatore, Ramnad, Madurai and Tirunelveli Districts of Madras.
6.8-8.4	7.5 (17)	5.2-6.3	5.7 (9)	31.4	53.53	Bijapur, Raichur, Dharwar, and Davanagere Districts of Mysore.
7.1-9.6	7.9 (14)	4.9-6.7	5.3 (7)	33.0	79.54-88.06	Aurangabad and Bidar Districts of Bombay.
6.8-8.9	7.3 (15)	4.4	4.4 (1)	36.0	85.88	Punjab.
6.9-9.3	8.1 (15)	5.0-5.3	5.1 (3)	32.5	84.22	Ujjain, Dewas, Indore and Mandsaur regions of Madhya Pradesh.

TABLE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
16.	320 F	Hirsutum	14.61-24.78	21.28 (15)	4.20-13.63	8.77 (14)	5.3-8.3	6.5 (15)
17.	Uppam, Tinnies	Herbaceum	15.80-25.60	18.85 (12)	5.89-15.23	10.51 (10)	4.9-5.9	5.4 (2)
18.	U. P. *Desi*	Arboreum	14.87-20.89	17.60 (13)	1.10-10.84	6.19 (13)	4.5-6.5	5.1 (13)
19.	Vijay	Herbaceum	17.45-23.00	19.53 (12)	1.92-10.55	5.15 (11)	5.1-6.4	6.0 (11)
20.	Jarila	Arboreum	17.25-21.23	20.12 (12)	2.22-11.00	6.62 (12)	5.1-6.8	5.9 (12)
21.	Red Northerns N 14	Arboreum	16.00-21.16	18.38 (10)	1.64-8.00	4.87 (9)	4.6-6.2	5.5 (6)
22.	Rajasthan *Desi*	Arboreum	15.82-23.22	19.75 (9)	6.00-13.25	8.42 (9)	4.6-7.3	5.9 (9)
23.	Mungari	Herbaceum	16.66-20.56	18.58 (9)	4.00-14.10	5.78 (7)	4.4-5.4	4.8 (3)
24.	Kalyan	Herbaceum	16.19-22.03	17.89 (9)	4.05-9.33	6.19 (9)	5.6-6.6	6.2 (6)
25.	Gaorani 6	Arboreum	17.67-22.04	19.49 (9)	1.64-8.10	4.32 (9)	4.8-6.9	5.9 (9)
26.	Rajasthan American	Hirsutum	17.20-21.53	19.63 (8)	8.04-13.43	10.83 (8)	7.1-8.6	7.8 (8)
27.	L.S.S.	Hirsutum	18.70-26.00	21.98 (7)	3.56-8.41	6.72 (7)	5.1-9.2	6.1 (7)
28.	H 420	Arboreum	18.01-21.22	19.65 (6)	1.70-8.60	6.42 (6)	5.3-6.7	5.9 (6)
29.	"35/1" Improved *Desi* of U.P.	Arboreum	16.62-21.47	19.21 (6)	8.11-12.58	10.42 (6)	4.9-6.0	5.5 (5)
30.	Pratap	Arboreum	17.20-22.71	19.63 (5)	3.33-7.76	5.40 (5)	4.8-7.7	6.0 (5)
31.	Parbhani American	Hirsutum	18.86-22.20	20.56 (5)	11.90-15.65	13.86 (5)	7.2-8.9	7.9 (5)
32.	M. P. *Desi*	Arboreum	17.74-20.00	19.21 (4)	3.67-7.04	5.70 (4)	5.9-6.4	6.2 (3)
33.	C. Indore 1	Hirsutum	21.11-25.33	23.03 (4)	7.22-10.00	8.67 (4)	6.0-7.3	6.7 (4)
34.	C 520	Arboreum	14.95-21.00	18.72 (3)	1.66-6.80	4.41 (3)	5.1-5.9	5.5 (3)

—1. *(Contd.)*

(10)	(11)	(12)	(13)	(14)	(15)	(16)
8.3-10.2	9.1 (15)	5.5-7.8	6.7 (5)	34.0	Included under Punjab and Rajasthan American	Rajasthan and Punjab.
7.6-8.4	8.0 (2)	5.5	5.5 (1)	29.0/30.0	32.68-34.29	Coimbatore, Madurai, Ramnad, and Tirunelveli Districts of Madras.
6.7-8.7	7.3 (13)	4.2-4.3	4.3 (3)	30.0/35.0	11.70-14.70	Uttar Pradesh.
6.8-8.2	7.4 (11)	4.9-6.4	5.9 (6)	39.4	93.96	Broach and Baroda Districts of Bombay.
6.7-8.8	7.8 (12)	...	...	36.4	Included under Virnar	M. P. and Bombay.
6.5-7.3	6.9 (6)	4.4-5.0	4.7 (4)	24.0	5.54 (Includes White Northerns)	Nandyal Taluk of Kurnool District, Andhra Pradesh.
7.2-10.0	8.4 (9)	5.9-7.8	6.9 (2)	30.0/40.0	39.12-60.85	Rajasthan.
7.1-8.1	7.6 (3)	...	...	33.0	17.06	Adoni and Tadipatri Taluks of Andhra Pradesh.
6.9-8.0	7.5 (6)	7.0-7.5	7.2 (4)	38.7	30.50	Zalavad Viramgaum, Mehsana and Ahmedabad of Saurashtra.
6.8-8.0	7.5 (9)	5.0-5.5	5.3 (6)	30.8	Included under Gaorani 12	Nanded, Bhimsa and Nirmal of Bombay.
9.4-10.3	9.8 (8)	8.3-9.9	8.8 (8)	33 1/3*	14.35	Udaipur.
8.2-11.3	9.0 (7)	7.0	7.0 (1)	34.0	Included under Punjab and Rajasthan America	Punjab and Rajasthan.
6.8-9.6	7.8 (6)	5.7	5.7 (1)	33 0/34.0	50.95-53.31	Madhya Pradesh.
6.7-7.5	7.1 (5)	4.4	4.4 (1)	36.8	Included under U. P. *Desi*	Uttar Pradesh.
7.0-7.8	7.6 (5	4.5-6.3	4.9 (4)	30.3	...	Gujerat and Rajasthan.
9.2-10.9	9.8 (5)	8.0-9.5	8.7 (3)	31.0	4.29	Adilabad District of Andhra Pradesh and Marathwada District of Bombay.
7.0-8.2	7.5 (3)	4.6-5.2	4.9 (3)	33 1/3*	0.25	Madhya Pradesh.
9.3-11.00	9.9 (4)	7.4-9.7	8.6 (2)	32.0	Included under Rajasthan American	Rajasthan.
6.9-7.4	7.2 (3)	5.5	5.5 (1)	40.0	Included under Rajasthan *Desi*	Rajasthan.

TABLE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
35.	Wagad	Herbaceum	16.84-17.55	17.20 (2)	5.00-5.85	5.42 (2)	5.8-6.5	6.1 (2)
36.	Selection 69	...	16.80-17.90	17.35 (2)	2.90-8.67	5.78 (2)	5.0-6.8	5.9 (2)
37.	Ganganagar 1 (G1)	Arboreum	20.78-20.90	20.84 (2)	4.00-10.56	7.28 (2)	5.1-6.1	5.6 (2)
38.	Oomras	Arboreum	16.65-18.56	17.60 (2)	7.35-7.85	7.60 (2)	6.1-6.7	6.4 (2)
39.	Kalagin	Herbaceum	18.11	18.11 (1)	5.67	5.67 (1)	5.4	5.4 (1)
40.	Suyog-Surti	Herbaceum	17.00	17.00 (1)	11.44	11.44 (1)	7.4	7.4 (1)
41.	Mathio	...	19.70	19.70 (1)	12.26	12.26 (1)	6.4	6.4 (1)
42.	Punjab American H-14	Hirsutum	20.10	20.10 (1)	12.67	12.67 (1)	7.8	7.8 (1)
43.	Raj (CO4-B-40)	Hirsutum	21.60	21.60 (1)	14.00	14.00 (1)	9.6	9.6 (1)
44.	Indore 2	Hirsutum	20.90	20.90 (1)	8.10	8.10 (1)	6.0	6.0 (1)
45.	Daulat 2204	Arboreum	19.44	19.44 (1)	5.00	5.00 (1)	6.2	6.2 (1)
46.	Bokda	...	17.30	17.30 (1)	4.78	4.78 (1)	6.2	6.2 (1)
47.	1027 ALF	Herbaceum	18.56	18.56 (1)	10.67	10.67 (1)	7.1	7.1 (1)
48.	134-C02-M (Devitej)	Hirsutum	15.67	15.67 (1)	12.33	12.33 (1)	7.6	7.6 (1)
49.	170-C02 (Deviraj)	Hirsutum	17.44	17.44 (1)	8.56	8.56 (1)	5.8	5.8 (1)
50.	Local Sannahatti	Arboreum	15.90	15.90 (1)	9.89	9.89 (1)	4.8	4.8 (1)

—1. *(Contd.)*

(10)	(11)	(12)	(13)	(14)	(15)	(16)
7.0-7.8	7.4 (2)	7.1	7.1 (1)	37.2	...	Saurashtra.
5.8-8.0	7.4 (2)	...	...	30.0	...	Mysore.
5.7-6.7	6.7 (2)	...	...	40.0	Included under Rajasthan *Desi*	Rajasthan.
7.7-8.2	7.9 (2)	5.1-54	5.3 (2)	33.0-35.0	0.55-0.60	Madhya Pradesh.
7.0	7.0 (1)	...	...	...	...	Surat District of Bombay.
.5	8.5 (1)	...	...	36.8	48.69	Surat District of Bombay.
7.3	7.3 (1)	...	...	32.0	20.83	Saurashtra.
9.5	9.5 (1)	9.5	9.5 (1)	35.4	175.32	Punjab.
11.3	11.3 (1)	...	...	...	...	Bombay.
9.6	9.6 (1)	...	...	32.0	Included under *Buri*	Madhya Pradesh.
7.8	7.8 (1)	6.8	6.8 (1)	36.2	...	Bombay.
8.7	8.7 (1)	...	...	...	...	Mysore.
7.7	7.7 (1)	...	...	...	Included under Vijay	Saurashtra.
9.6	9.6 (1)	9.2	9.2 (1)	33.7/35.5	...	Saurashtra.
8.4	8.4 (1)	7.4	7.4 (1)	36.4/38.4	...	Saurashtra.
7.6	7.6 (1)	...	...	...	...	Mysore.

The higher residual lint contents of American-type seed over those of many varieties of *desi* seed result in certain peculiarities regarding the relative prices of the two types. For instance, the prices of the Lakshmi variety of seed, high in oil and residual lint, are lower in the local markets than those of Hingari or Farm seed, which contain less oil and lint, whereas the reverse ought to be the case. The reason for this anomalous position is as follows: as cottonseed has been solely used as cattlefeed till now, the high fuzz of the American variety seed is not relished by cattle, which relish the relatively low-lintered *desi* seed. In the U.S.A., on the other hand, where separate industries have been established for the utilisation of linters, every effort is made to recover most of the linters from the seed both when ginning the seed cotton and when delinting the cottonseed. With the increasing demand for linters in the rayon, paper, chemical, cotton and cellulose industries in our country, the need to recover all the linters possible from cottonseed in India also will become quite essential. The prices of American-type cottonseed will then be more than that of *desi*-type seed. So far, the linter-rich seed has only to find its market with the cottonseed crusher having delinting equipment, or sold at lower prices for cattle feeding.

To remedy the above situation, it is suggested that delinting equipment now generally installed at cottonseed crushing mills may be established at the ginning factory itself. If this is done, it would not only prolong the working time of ginning factories (gins work for about 12 weeks a year in any locality in India) in producing linters of various grades, but it will enable the delinted seed thus obtained to be sold to the cottonseed miller at a higher price. The delinted seed could also be sold as cattlefeed at a higher price and would be richer in oil and protein contents than the original seed. Another advantage of adopting this procedure would be to reduce to some extent two other problems, namely, the storage of huge quantities of ginned seed both at the ginning mills till they are sold and at the seed-crushing mills afterwards, and the elimination of seed-cleaning and delinting processes by the cottonseed crusher. If adopted by the ginners this procedure will also eliminate the possibility of any significant amount of refraction entering into the delinted seed bought by the crushing mills.

Data on the length of the seed and seed index will be of use in devising seed-cleaning equipment and suitable sizes of the screens to separate different size seeds, bolls, etc.

The main object of presenting the data on the composition of commercial cottonseed in this paper is that it would be of direct interest to the miller, though the data may be of some interest to plant geneticists, agriculturists and ginners. Selection and breeding work for improvement of cotton in India has so far been guided only by considerations of lint character and yield, and variations in linter or oil contents of seed of the present varieties have occurred more by chance than design. Trade practices have made the physical division of seed-cotton into staple cotton (lint) and cottonseed so common that this differentiation is accepted in a manner which suggests that these two are distinct products derived from the cotton plant. But staple cotton is as much a product of the cottonseed as are oil, linters, kernels and hulls. We therefore believe that the time has come when breeding and selection work should also be directed to evolving some strains high in seed oil and protein contents for gainful utilisation for crushing and as cattlefeed, as already stressed by Uppal. He stated[16] that " the use of cottonseed in India as cattlefeed makes it desirable that varieties with higher oil content should also be produced. Work done in other countries has shown that this can be achieved without detriment to fibre development."

Acknowledgment

We have fully drawn upon the already-published data of this Institute on the composition of 230 samples of Indian cottonseed and also on the yet unpublished data pertaining to the remaining 310 samples. We thank Sri C. R. Desikan, Sri A. V. Ramana, Sri R. Kasi Viswanatham, former Research Chemists and Sri V. V. Krishna Rao and Sri S. D. Thirumala Rao, Research Chemists of this Institute for the analytical data worked out by them. We thank the Indian Central Oilseeds Committee who financed the scheme under which a part of the work presented in this paper was carried out.

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DISCUSSIONS

DISCUSSION LEADER: DR. K. S. MURTI,
Oil Technological Institute, Anantapur.

PAPER 1.

K. S. Murti: 1. Similar imbibition work on *barbadense* seed may be useful.

2. Studies on the effect of residual lint content and hull thickness on the imbibition, and the time-lag between imbibition and germination, may be interesting.

3. The effect of adding plant hormones (auxins) on the imbibition may be studied.

4. The relative efficiency of cottonseeds compared with other classes of cereals like paddy, sorghum, etc., with respect to their imbibition may be interesting in connection with raising mixed crops of cotton with others.

5. Mr. Dubash is requested to explain imbibition.

P. J. Dubash: (with the help of a drawing on the blackboard):

A young cell with no vacuoles is incapable of osmotic activity. Hence water has to be absorbed by imbibition. Recent work has shown that the borderline between imbibition and osmosis is difficult to define. A young seed has no root. It cannot absorb water by osmosis before the vacuoles can be formed and hence does so by imbibition. The problem was to find out if all the varieties of cottonseed imbibe water at the same rate. Biochemical processes begin on taking up water. This activates the radicle which comes out immediately or after a time-lag. On this time-lag rests the principle of vernalization. Lysenko retarded growth by freezing but at the same time development was allowed to continue. This constitutes vernalization.

J. M. Shah: Certain varieties like Jarilla and 197/3 are sown in June but the crop matures very quickly and is out in October. Varieties like Vijay and 1027 grown in Surat are also sown in June, but the crop take long to mature and come out in February. Is there some relation between crop maturity and imbibition? Late maturity, particularly after December, exposes the crop to the danger of frost attack.

N. K. Iyengar: Shri Dubash's work is very important as it will provide factors for promoting earliness in cottonseed. Can we devise a method by which the seeds could be treated to make them mature earlier?

G. S. Chowdhury: There is a need for attention to the engineering aspects of cottonseed, particularly in relation to whether the seeds have hard shells or soft shells. Uniform size and hardness should be developed.

I. K. Kishore: Since imbibition is a purely physical process, how is it affected by factors like the thickness of the hulls, the chemical constituents of the hulls (like gossypol, etc.), and the hydrophobic and hydrophilic substances present?

K. S. Murti: The subject is important as it is connected with the promotion of germination and hence with production of cottonseed. Our channels of work should include such work on fundamental aspects, and indeed these must be given top priority.

P. J. Dubash (replying): To the question of the utility of this work, I would repeat a story: When Faraday was asked by an old lady what was the use of electricity, he replied 'Madam, what is the use of a new-born baby?'

As regards the first two questions on earliness, the work is still in an experimental stage. It is not possible to state when one can supply vernalised seed to the farmer. I shall however mention a few observations on this work. We studied imbibition in Lakshmi seed at regular intervals of time. Studies of sections indicated that cell-division started and the embryo began to get activated in the first 15 minutes of imbibition; probably some hormone is involved in this process. In the next 15 minutes conducting strands (which form the vessels of the plant) begin to develop, and at this stage the embryo begins to absorb water through these strands and not entirely by imbibition but by osmosis as well. After the first hour of imbibition, cell specialisation advances. Pigment glands begin to develop and when they come in contact with water, gossypol is released. This is known to stimulate growth of the radicle.

Also vacuolisation begins whereby a living cell begins to lose all the protoplasm and becomes empty. The plant is thereby preparing itself for translocation.

We plan to vernalize the seed by freezing at various stages of imbibition and compare the results.

The influence of various constituents on imbibition has not been studied.

Studies on the *barbadense* variety will be taken up.

Regarding the influence of hull thickness and the presence of linters on the time-lag, Simpson has already observed that thickness is important, but we feel that plants have their own means of activation and gossypol may play an important role.

Addition of auxins is a good suggestion and we are also thinking on the same lines.

PAPER 2.

K. S. Murti: 1. This variety of cottonseed has an advantage over other varieties in that no delinting will be necessary and as it contains a high percentage of oil.

2. As the St. Andrews variety of cottonseed is stated to be naked unlike most other varieties, it will be desirable to study its storage behaviour at different humidities.

3. As cottonseeds belonging to the species *G. barbadense* are reported to contain a higher amount of pigments, it would be of interest to study the pigmentation of this cultivated variety also.

4. The oil content of *barbadense* species of cottonseed (Egyptian and Sea-Island varieties) produced in Egypt and the U.S.A., are reported to be respectively 23.0-24.5% and 22.0 to 24.0% compared to the 20% oil content of this St. Andrews variety here.

J. M. Shah: If the Government wants to extend the cultivation of St. Andrews cotton to the extent of 3 lakh acres, would the soil of Gujarat and Surat district, where the average rainfall is 40 inches, be suitable for the growth of this variety? There is a great dearth of long-staple cotton in India and it will save a great deal of foreign exchange if the cultivation of this variety is extended. It will also be of great benefit to the oil industry, since the oil content of the seed is about 20% and the seed is bold.

R. K. Bhatnagar: Can it be grown in the U.P. in areas where there is good rainfall and drainage?

Burhanuddin Hussain: In non-coastal areas of Andhra Pradesh, where the rainfall is about 40 inches, particularly in Adilabad district American Parbhani cannot be grown successfully. Besides soil conditions, what is the temperature and rainfall required for cultivation of this variety?

T. V. Subba Rao: It is stated that the oil content of the seed is 20%. Is this the oil in the seed or oil that can be recovered?

V. K. Parikh: What type of pigments are present in the seed and what are the refining characteristics of the oil?

B. S. Lulla: What is the resistance of the St. Andrews variety to pests and diseases of cotton, when grown in different climatic regions and soils of the country?

S. Zainul Abideen: Cottonseed is grown in irrigated areas. It can replace other oilseeds also; what are the economics of this? Cottonseed gives not only oil but also other products. The soil determines the linter length. Ordinary cultivated soils other than black soils, will give seeds with less linters. The production of American varieties is desirable on account of its many advantages which make it more economical than *desi* seed. Is there any research in progress to cultivate varieties for high oil and high linter contents?

N. B. Naidu: The production figures of this cottonseed of 45,000 lb. is based on a ginning percentage of 33%. According to Dr. Murti, calculations should be based on the actual linter content of individual varieties. I would like to know which is the correct basis.

B. P. Maheshwari: By-products are important items in the cottonseed industry. We are already short of linters. Cattle-owners should not be encouraged to grow this variety of lintless seed as it would affect the disposal of cake.

K. S. Murti: Shri Iyengar has calculated on the actual ginning percentage basis for this particular variety which is the accurate way to estimate the quantity. The objection in our paper was only to the use of general figure of 33⅓% for calculation of seed production for all varieties of seed.

N. K. Iyengar (replying): This cotton is new to India. The British Government in India then were not much interested in it. It has now been decided to encourage this cotton, to save on foreign exchange and since imports of foreign cotton are being curtailed. The staple lengths required for our mills are 1.25 to 1.50 inch. This cotton is not meant to be grown in areas like Broach and Surat where other varieties are grown, as it would lead to deliberate contamination and mixture. An expert committee has been studying this question of allocating suitable areas for the development of this cotton. Kerala, Assam and the Malnad areas of Mysore have been thought to be suitable. This variety requires heavy rainfall and thrives well in areas receiving 100 inches of rainfall, but it can also grow in areas having about 40 inches provided they are located at altitudes of 3000-4000 feet. It is not suited for cultivation in the plains where rainfall is low. This cotton is a delicate one and very sensitive to pests and diseases, especially boll worm, and to drought when the bolls are developing. All these points will have to be considered carefully. About 30,000 acres is programmed for 1959-60 and the results will be carefully studied. As regards the hybrids referred to, the Indian Central Cotton Committee has a scheme for hybridisation. Crosses of American and Asiatic cottons have been effected and strains developed.

The oil content of this variety is about 20%. The Sea-Island cotton varieties containing higher oil, about 24%, are not suitable for Indian mills since their staple is too long. St. Andrews is suitable for spinning 60-80 counts and efforts are being made to improve the cotton. The improvement in oil content will be taken up at a later stage.

K. S. Murti: We do not yet know the repercussions that would follow the development of this cotton. In reply to Shri T. V. Subba Rao, 20% is the oil content of the seed but the availability would be about 15-16%. This new variety should be welcomed since no delinting would be required. There is an overproduction of linters at the present moment and there should be no danger to the linter market by expansion of this variety. Similarly the importance of cake feeding is being realised and this variety will not constitute a hindrance to the cake market.

PAPER 3.

K. S. Murti: 1. The suggestion of the authors for setting-up a coordinated body of cotton technologists and cotton research workers deserves consideration. Such a step would go a long way towards assessing the production of cottonseed accurately and for fixing targets for stepping up production. The improved types of seed should be analysed for their characteristics as soon as produced.

2. I fully agree, and in fact have advocated since 1954, that the actual ginning percentage of each variety in each locality should be taken into consideration for purposes of estimation of the seed production, as now suggested by the authors (*Oils and Oilseeds J.*, 1954, *6*, 11).

3. The authors have not included among the varieties grown in Andhra, the Laxmi variety which is grown in considerable quantities in the districts of Kurnool and Cuddapah. The reason for their not classifying this separately may be because separate statistics for this variety are not maintained in the Andhra Pradesh State. As this is the best variety grown in Andhra Pradesh in large quantities, it may be separately classified in future.

M. Venkoba Rao: It is often forgotten that the sowing of seed varies from tract to tract, and that consultations with breeders are often helpful in estimating production.

PAPER 4.

K. S. Murti: 1. There is need to adopt uniform terminology regarding the following terms: linters, fuzz, residual lint, residual linters. The authors have used the expressions "residual linters", "true linters", "apparent linters" and "linter content." According to Bailey, the correct expression seems to be linters and A.O.C.S. Methods use the expression "residual lint" to connote the same. Linters usually refers to all fibres left on the seed following ginning, that can later be removed quantitatively, and includes both lint and fuzz fibres (fuzz usually denotes the same removeable fraction). Therefore, I suggest the use of "linters" uniformly, and its value may be expressed as "residual lint, per cent."

2. The authors explain the higher linters content of the *desi* seed found in the work of Murti and co-workers as due to the inefficiency of the Indian gins, which raises the "apparent" linter contents. Firstly, the effect of inefficient gins on the residual lint content of the seed is common to both the *desi* and American variety seed. Secondly, according to some, the saw gins used extensively in America leave more residual lint on the ginned seed than the roller gins almost exclusively used in India. Taking both these factors into account, their explanation does not seem to account for the higher lint contents of *desi* seed.

C. R. Das: *Desi* seed has a low seed index. What influence does this have on delinting and dehulling processes?

S. Raghavendar Rao: It would be desirable to adopt a more rational nomenclature based on the botanical or regional name of cottonseed varieties than to class them as *desi* and American. This is all the more necessary when Murti and his co-workers have found that more than 50% of the so-called *desi* varieties contain more than 5% linters.

K. T. Achaya: Perhaps acid delinting and microscopic study may help to distinguish between residual cotton fibres and true fuzz. Seed index is not the same as seed size and Dr. Murti's figures for length and breadth of cottonseeds should be very valuable to processers.

K. S. Chari: Seed index is very useful in the processing of cottonseed, as it indicates the size of the seed, which conditions various operations. During seed-cleaning, the perforations of the seed-cleaning unit will have to be adjusted according to seed size. The opening between the rake teeth and the ribs of the delinter will also have to be adjusted while delinting. Even during hulling, the distance between the discs in the disc-type of huller, or the clearance between the concave and the rotor in the bar-type of huller, will have to be adjusted according to the size of the seed. Hence the seed index is a very important measurement finding immediate application in processing.

G. V. Sirur: It is desirable and also scientifically correct to classify seeds according to botanical origin, i.e., as *hirsutum, herbaceum, arboreum* or *barbadense.*

K. S. Murti. The terms *desi* and American are implanted in the minds of traders, agriculturists, etc. Will it help them now to change the names according to the variety?

N. K. Iyengar: I would suggest that accepted trade variety names should be used for identification under the broad classification suggested by Shri Sirur.

PAPER 5.

K. S. Murti: 1. It is desirable that standard, uniform Methods of the A.O.C.S. be adopted for future work by all workers in this field, in order to obtain comparable results.

2. While the method described in the paper for the determination of hull content may give accurate results for pure experimental samples, it may not be applicable to commercial samples containing bolls, deteriorated seeds, etc. The quantity (1 gm. of delinted seed) taken may be inadequate; this may be fixed at least as 5 gms. to give representative and accurate results.

3. While some *desi* seed may be directly crushed for oil, many of the *desi* varieties contain a higher percentage of linters. Any variety containing over 5% linters should be delinted.

N. G. Chatterji: The paper states that very little oil is left in a solvent-extracted cake. This would seem to imply that solvent-extracted cake is not good for cattle feeding, but this is at variance with the opinion of many others. Extracted cake is largely exported to European countries for cattle feeding.

J. M. Shah: Delinting of 197/3 seed, known as Virnar, and of Jarilla-type seed is not a paying proposition, but it is absolutely essential to delint in the case of American seeds or Buri seed where the average lint content is 3.5 to 4%. The average yield per acre of cotton, which has a great bearing on the economics of our country, has not been properly tackled or mentioned in the present symposium papers. The average yield in India is only 80 to 100 lb. per acre whilst in the U.S.A. and U.S.S.R., it ranges from 400 to 500 lb. per acre. In order to make our economy more sound it is absolutely essential to increase our yield per acre without which our economic problems will not be solved. The relative data on yield per acre of cottonseed should also be given.

Burhanuddin Hussain: Large quantities of cottonseed are required as cattlefeed. Why not restrict crushing to only some varieties like *hirsutum* and leave the others for use as cattlefeed? Will it be possible to delint indigenous cottonseed easily with equipment now available?

T. V. Subba Rao: For cost estimations, information on the variations in oil content of seed produced from the different species of the plant and from different areas in the country would be helpful. Averages alone are not of much use and one looks for data recording sample-to-sample variations for such cost estimations. Also correlations between lint, protein and oil content are important.

The yield of cottonseed per acre in India has increased only from 146 lb. in 1938-39 to 187 lb. in 1956-57 while in Russia, it was about 979 lb. in 1956-57. Is it possible to develop in our country a variety of cottonseed that would be of economic value more for its yield of seed than as a source of cotton?

K. S. Murti: Every variety of *desi* seed cannot be delinted, but all those containing more than 5% linters should be delinted. We have published a lot of data which indicate that a considerable number of *desi* varieties do have more than 5% linters. While low-lint varieties can certainly be delinted, the economics and the oil and cake quality must be considered. From actual experiments we have found that direct crushing results in a low yield of oil. The colour of oil and its quality depend upon using modern, full-processing methods.

It is not desirable to feed whole seed to cattle; the cake is much superior, having more than 40% protein in contrast to only about 20% in the whole seed.

We have delinted *desi* seed to leave only 2.5 to 3% linters. Since the production of American seed today is only 25%, should we neglect the remaining 75% of *desi* seed?

In reply to Shri Subba Rao, I would like to state that we have published data on 320 representative samples of cottonseed, with about 250 unpublished analyses.

N. K. Iyengar: It is important that large areas be brought under irrigation and the effect of irrigation and manuring on cottonseed be studied. Irrigation does not seem to affect the oil content but does affect nitrogen.

(Kumari) I. G. Bhatt (replying): As stated in our paper, our purpose has been to estimate the oil content of cottonseeds by a uniform method and supply the data to the breeders to help them to breed for higher oil content. The A.O.C.S. Methods have been slightly modified as we had to carry out a large number of tests. Speed and economy were taken into consideration while introducing the modifications. Thus 1 gm. samples and fractionated solvent oil (fraction B.P. 65-66°C) have been used in all our experiments. These modifications however are not likely to affect the accuracy of the results to any great extent. Seeds used for our work were pure varieties obtained from breeding stations. Our data show that the lint content for the *desi* variety was low, about 4.7% and recommendations were based on this. After solvent-extraction only 1%of oil is left, but if mixed feeds are used, the necessary 4% oil can be made up from other sources.

K. S. Murti. The A.O.C.S., Method recommends that solvent of b.pt. 40-60°C. should be used for oil extraction; using 60-65°C. solvent may make some difference. It is also recommended in the standard A.O.C.S., Method that the seed should be dried, fumed with hydrochloric acid and ground before extraction of the oil.

PAPER 6.

K. S. Murti: 1. From the data presented in this paper, the oil and linters content should be evaluated statistically rather than given as arithmetical averages.

2. There is need for doing analytical work on the oils obtained from authentic samples of seed, as has been done by Vollertson for the American Oil Chemists' Society in the U.S.A., determining all characteristics of the corresponding refined oil.

3. The analytical data obtained on certain varieties is meagre and many more samples of those varieties should be done.

K. T. Achaya: The anomalies in the linter content of *desi* and American-type seeds may depend, as stated by Dr. Murti, upon the ginning efficiency. Ginning under standard conditions in the laboratory of known cottons may be worth doing, with subsequent estimation of linters.

It is also better to give analyses on a moisture-free basis since moisture is variable; this would greatly simplify plant calculations.

It is obviously advantageous to produce a quality of seed which is high both in oil and lint content, and work abroad has shown that this is possible.

B. M. Jindal: While the Punjab *desi* cottonseed is reported to contain 20% of oil it yields only 9% oil on crushing. Does the seed really contain 20%?

(*Kumari*) *I. G. Bhatt*: The production of the American variety in India is 25% of which 11% is grown in Punjab. Even if we process all the Punjab varieties the quantity of linters obtained would not be very considerable.

T. V. Subba Rao: It is important to give also the original moisture content. Results given on a 10% basis lead to practical difficulties if the original moisture content is not given.

B. P. Maheswari: Is it better to delint at the gins?

J. M. Shah: Regarding ginning and delinting, one must be acquainted with the general marketing condition prevailing in the country. The cotton is brought into the market by agriculturists and purchased by merchants, who are mainly cotton merchants and not interested in the delinting of cottonseeds. Moreover as their main business is in cotton they would not care to delint the seeds properly. Neither are the gin owners interested in this proposal because they are keener on getting a greater output per gin. Consequently linters are not easily saleable and it will be a great problem for ginners to dispose of them. Therefore it is not a practical proposition to get the cottonseed delinted at the ginning factories.

K. S. Murti: (replying): It is erroneous to think that cotton is the main product and seed is a by-product. If delinters are installed at ginneries the difference between *desi* and American seed will not arise. The differences in residual lint are partly due to ginning inefficiency. Saw gins are better for American seeds than for the *desi* variety. It is true that anomalies do exist but perhaps these are more in the nature and composition of seed rather than a function of gin efficiency alone, which would apply both to *desi* and American varieties equally. It is not possible to determine the true linter content by simple delinting in experimental linters. Our object has been to give data on commercial varieties, and for oil and linters contents the values have been given on a dry basis in this paper. In our earlier papers on the composition of cottonseed, the oil and linters contents are given on an 'as-is basis' and for comparison on a 10%-moisture basis also. Answering Kumari Bhatt's question, the Punjab varieties show great variations, sometimes having high and sometimes low linter contents; they do contain 21% of the oil on an average. Samples of seed used in our studies were sent after sampling by the Agricultural Departments of various states.

SECTION II

PROCESSING, STORAGE & KEEPING QUALITY

Discussion Leader: Dr. K. S. Chari,
Regional Research Laboratory,
Hyderabad.

1. PROCESSING OF COTTONSEED—DELINTING AND DEHULLING

By

K. S. CHARI, S. A. SALETORE & S. H. ZAHEER
(*Regional Research Laboratory, Hyderabad*)

The position of cottonseed processing in India is reviewed and the lack of data in respect of delinting of seeds is emphasised. The data obtained by processing a commercial variety of cottonseed are presented and the results discussed. The results indicate that as the yield of "first-cut" linters is increased, the power required is disproportionately high and the quality of linters is low.

The yield of linters by "mill-run" is higher than by two cuts and the power consumption for cutting a unit weight of linters by "mill-run" is lower than for the double cut.

The results of continuous working of 54 tons of a commercial variety of cottonseed are presented and the costing indicated.

Introduction

India is one of the major producers of cottonseed in the world and the production is estimated at 1.7 million tons in 1956-57. Most of this is used as cattlefeed with hardly 6% being crushed. In general, there are two distinct types of seed grown in India—one of low seed weight, linter content and oil content (*desi* seed) and the other of high seed weight, linter content and oil content (American). The present production of the high-lintered variety is about 30% of the total, but is expected to rise to 40% by the end of the Second Plan.

The high-lintered variety, containing about 13% of linters compared to about 4% for the low-lintered variety,[2] is disliked by cattle owners because of its high lint content and sells at a lower price than the other.

Most of the existing cottonseed processing units in India obtain only the "mill-run" quality of linters, which are either exported or supplied to the rayon industry in India. No data are available on the yields of linters by various cuts, power consumption, cost of production or their quality when derived from Indian cottonseed as has been done in America.[3] However, the analysis and grading of some varieties of Indian linters were done some years back.[4] Detailed analysis of a number of varieties of cottonseed and pilot-plant studies of some of them have been recently reported.[5] A considerable amount of work on the delinting of Laxmi variety of seed has been done in this Laboratory.[6,7]

Experimental

The cottonseed used for the study was a commercial variety containing high and low-lintered varieties in the proportion of 78:22 (estimated by hand segregation). The lint content

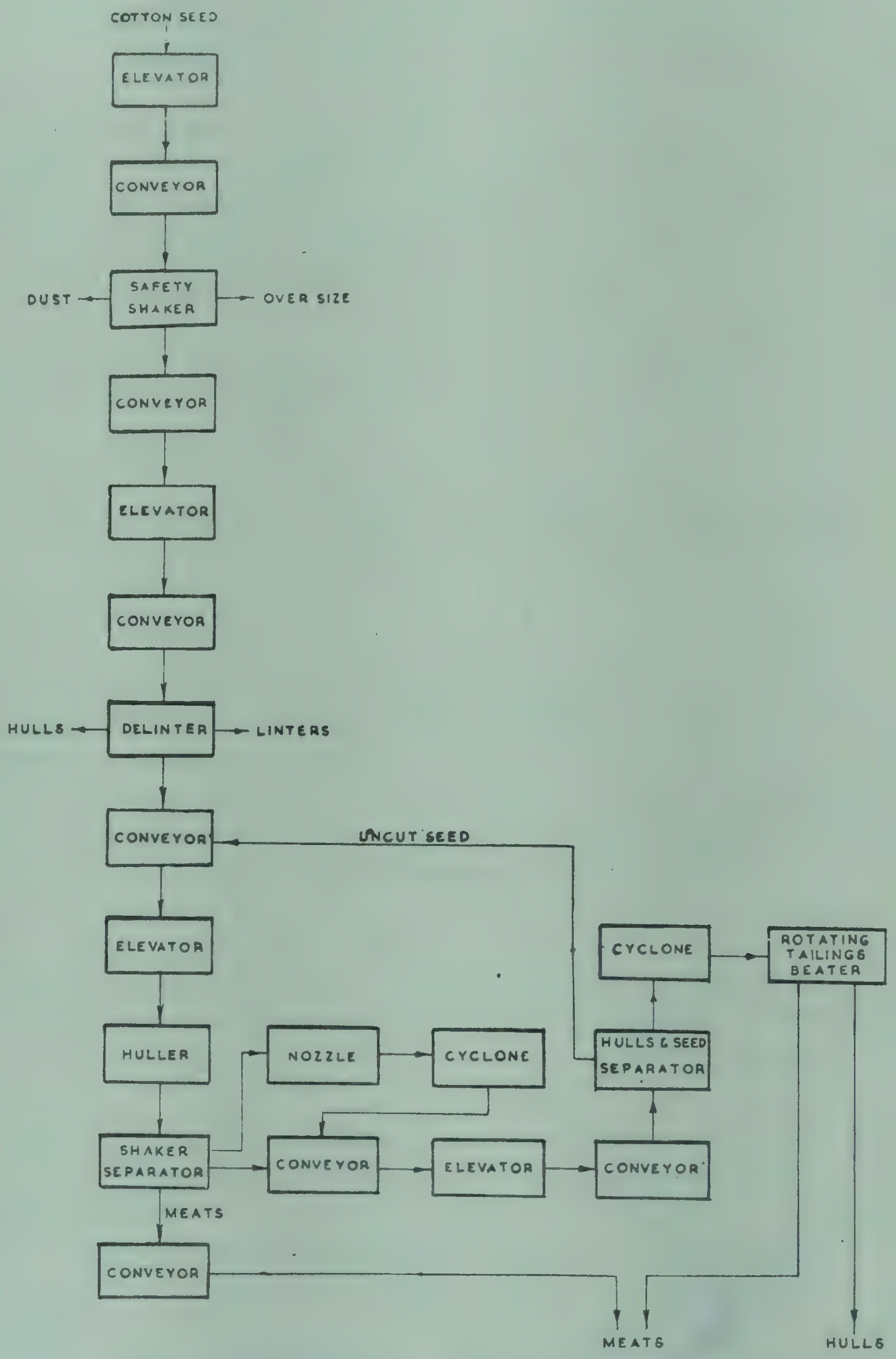
COTTON SEED
ELEVATOR
CONVEYOR
DUST
SAFETY SHAKER
OVER SIZE
CONVEYOR
ELEVATOR
CONVEYOR
HULLS
DELINTER
LINTERS
CONVEYOR
UNCUT SEED
ELEVATOR
CYCLONE
ROTATING TAILINGS BEATER
HULLER
NOZZLE
CYCLONE
HULLS & SEED SEPARATOR
SHAKER SEPARATOR
CONVEYOR
ELEVATOR
CONVEYOR
MEATS
CONVEYOR
MEATS
HULLS

FIG. 1. FLOW SHEET FOR COTTON SEED PROCESSING

of the mixture and its separated components on an 8% moisture basis was as follows:

Mixture ...	... 10.86%
High-lintered component	... 13.15%
Low-lintered component	... 4.31%
Mixture (calculated)	... 11.21%

The arrangement of equipment used is shown in Fig. 1 in the form of a flowsheet.

During delinting, the roll density and the saw projections were kept constant, but the openings between the rake teeth and the ribs were adjusted by altering the position of the studs (three positions) and by setting the eccentric of the seed board to various values (0, 5, 10, 15 and 20). The rate of feed was adjusted by altering the number of teeth (one, two or three). This should result in 45 runs, but some of the combinations were found unsuitable as the seeds either passed through without getting delinted or were delinted to the point of being damaged.

First-cut linters. For each run, 392 pounds of seed were used; for the various positions of stud, index and teeth, the time for delinting, power consumed and the yield of linters were observed. The quality of linters was assessed by analysing for ash, Shirley loss and yield of chemical cotton.

The results are shown in Table I. The data in Fig. 2 indicate that as the lint cut is increased, the power consumed is disproportionately high.

The data shown in Fig. 3, though spattered, generally indicate that the ash content is low when the yield of linters is low. When the yield of linters is high, the ash content increased considerably, probably due to the removal of dust and other impurities embedded in the seed.

Results on the Shirley analyser (Fig. 4), which estimates the clean lint and hence the quality of linters, show that as the lint cut is increased, the Shirley loss increases disproportionately.

The yield of bleached linters is an important criterion when the linters are intended for rayon and other chemical uses. The data in Fig. 5 indicate that the quality of linters deteriorates as the yield of linters is increased.

The cost of production of linters has been estimated for each run, with the main assumption that the delinted seed would fetch the same price as raw seed. The data in Fig. 6 indicate that as the linters cut per day increases, the cost per pound decreases though it is necessary to remember that the quality deteriorates.

Second-cut linters. The first-cut seeds were subjected to a second-cut with the adjustment to cut the maximum linters without damaging the seed. The results are shown in Table 2. The yield of linters is low and the quality of linters, judged by the higher Shirley loss and lower yields of bleached linters, is poorer than that of first-cut linters. The cost per pound decreases as the amount of linters cut is increased (Fig. 7), but the cost per pound of linters is much higher than for first-cut linters.

Delinting and hulling. With the adjustment to give maximum linters in one operation without damaging the seed, three batches each of 0.5 ton of seeds were run through the entire

TABLE I

Effect of Adjustments Made on Linter Machine on the Yield and Quality of First-cut Linters

(Wt. of seeds taken for each run, 392 lbs.)

Run No.	Adjustment			Time, *min.*	Power, KWH.	Yield of linters			Ash in linters %	Shirley loss %	Yield of bleached linters %	Cost per lb. *nP.*	Power consumed per lb. KWH.
	Stud	Index	Teeth			*lb.*	*%*	*lb. per day.*					
23	O	0	1	80	6.0	13.5	3.44	242	3.64	...	...	33	0.345
24	O	0	2	45	6.0	14.0	3.57	447	4.79	32.2	76.2	20	0.428
25	O	0	3	40	5.5	14.5	3.70	521	...	...	...	17	0.380
26	O	5	1	75	6.0	10.5	2.68	202	6.13	...	...	40	0.570
27	O	5	2	45	6.0	10.5	2.68	336	2.90	31.2	77.3	25	0.570
28	O	5	3	35	4.0	10.5	2.68	432	7.04	...	...	20	0.381
12	M	0	1	85	9.0	18.5	4.72	313	4.27	...	...	27	0.487
14	M	0	2	55	8.0	17.0	4.33	445	6.83	42.6	77.2	20	0.471
18	M	5	1	90	9.0	15.5	3.96	248	5.58	...	...	33	0.582
17	M	5	2	45	5.5	13.5	3.44	432	2.53	...	...	20	0.407
16	M	5	3	45	5.0	12.0	3.06	384	5.29	...	...	22	0.417
19	M	10	1	85	5.0	15.5	3.96	263	3.95	47.5	78.4	29	0.323
20	M	10	2	50	6.0	13.5	3.44	388	2.79	...	...	22	0.444
21	M	10	3	50	4.0	13.5	3.44	388	4.05	...	...	21	0.296
22	M	20	3	50	4.0	2.0	0.51	58	0.36	...	...	139	2.000
29	I	9	1	80	10.0	16.0	4.08	288	3.70	...	...	30	0.625
5	I	10	1	75	7.0	17.5	4.47	336	3.07	57.6	75.8	24	0.400
3	I	10	2	60	7.0	19.5	4.97	468	6.87	29.8	70.0	18	0.359
4	I	10	3	50	7.0	16.5	4.21	475	4.29	...	...	19	0.423
6	I	15	1	70	6.0	14.5	3.70	298	3.40	...	...	27	0.413
7	I	15	2	40	5.0	13.0	3.32	468	2.96	...	...	19	0.385
8	I	15	3	40	5.5	12.0	3.06	432	3.74	31.8	76.8	20	0.457
11	I	20	1	75	6.5	15.5	3.96	290	3.10	...	...	28	0.418
10	I	20	2	40	5.0	13.0	3.32	468	6.28	...	...	19	0.384
9	I	20	3	40	5.0	13.5	3.44	486	4.99	...	...	18	0.371

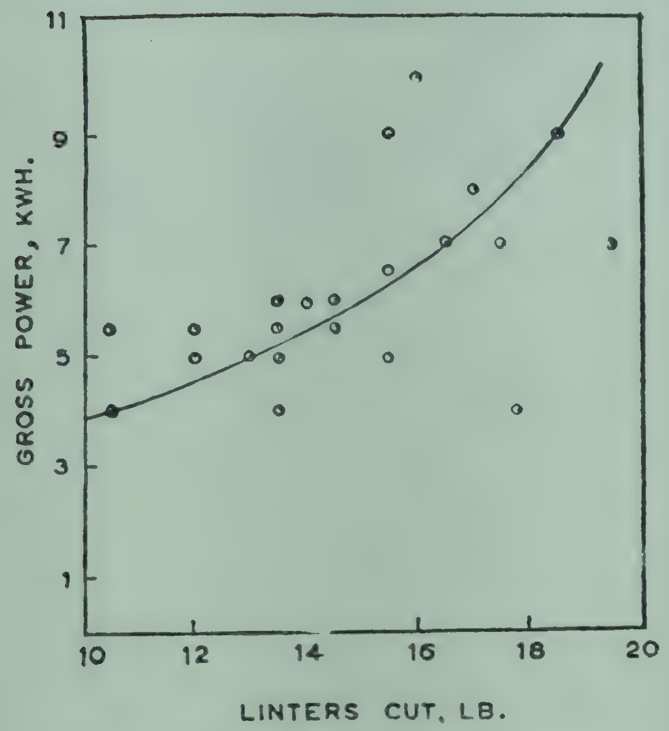

Fig. 2. Gross power vs. linters cut for first-cut.

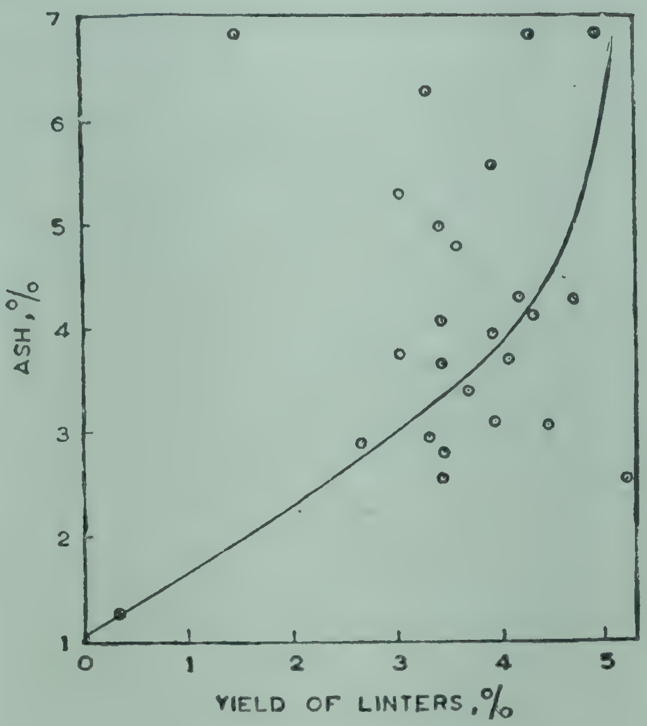

Fig. 3. Yield of linters vs. ash in first-cut.

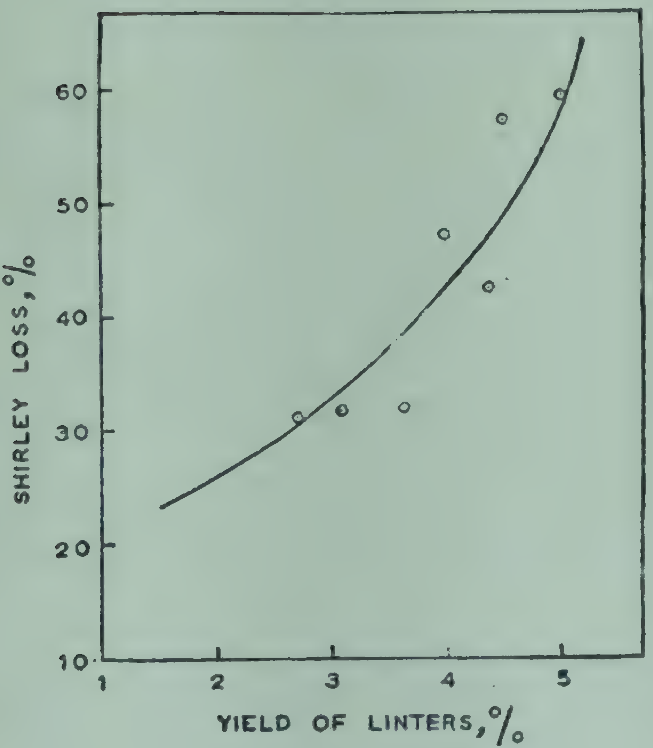

Fig. 4. Yield of linters vs. Shirley loss in first-cut

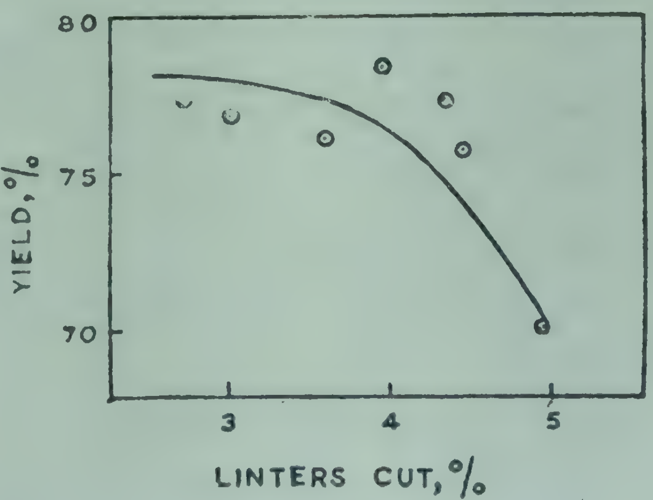

Fig. 5. Percentage linters cut vs. yield of bleached linters.

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TABLE II

Yield and Quality of Second-cut Linters

Run No.	Yield of linters		Ash in linters %	Shirley loss %	Yield of bleached linters %	Cost per lb. *nP.*
	%	lb. per day				
52	1.74	181	3.61	...	...	48
53	1.37	111	3.01	63.5	...	72
54	1.37	112	3.46	...	...	76
55	1.44	111	3.23	...	...	72
56	1.55	132	3.68	59.6	...	63
57	1.54	132	3.80	...	...	62
41	0.72	80	4.32	...	...	104
43	0.56	72	3.54	69.2	74.6	115
47	1.04	101	3.64	...	..	80
46	1.11	112	4.71	...	...	74
45	1.00	92	3.09	...	...	89
48	2.27	222	3.69	64.7	...	37
49	1.37	111	3.64	...	...	74
50	1.41	120	2.98	...	...	67
51	3.92	229	3.38	...	...	35
58	0.86	79	4.09	...	...	104
34	0.73	103	7.22	70.3	66.3	85
32	0.98	112	8.47	67.6	...	74
33	0.84	87	5.33	...	...	92
35	0.85	72	4.35	...	...	110
36	1.00	112	5.77	...	...	78
37	1.00	105	3.52	60.4	77.5	77
40	1.10	105	4.32	...	...	78
39	1.13	109	3.69	...	...	76
38	0.98	101	3.20	...	...	82

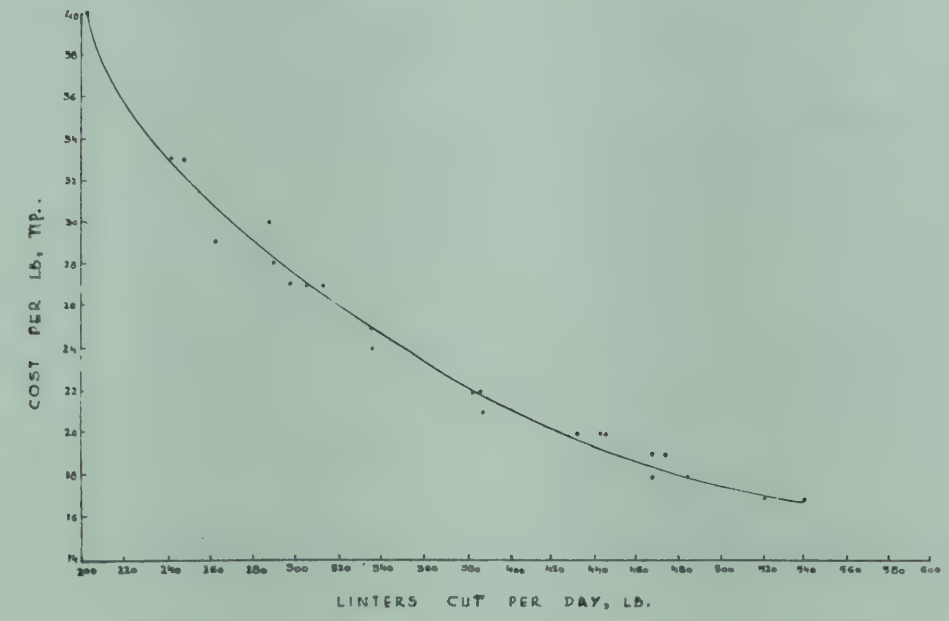

Fig. 6. Yield of linters vs. cost per pound of first-cut linters.

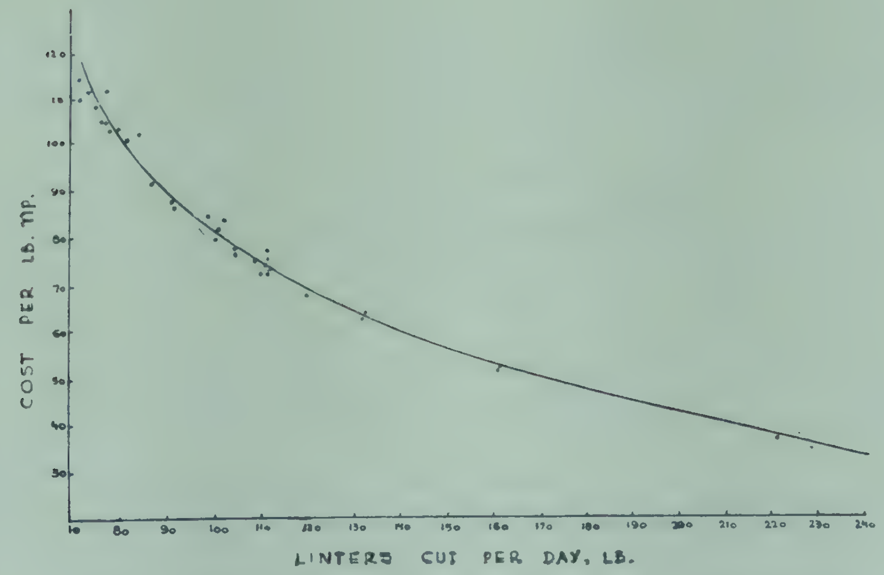

Fig. 7. Yield of linters vs. cost per pound of second-cut linters.

TABLE III

Yields of Products by Mill-run and Double-cut

Products	Mill-run %	Double-cut First-cut %	Double-cut Second-cut %	Double-cut Total %
Linters	5.4	2.7	1.3	4.0
Dust	2.8	2.1	0.8	2.9
Oversize	0.4	0.2	0.1	0.3
Hulls below linter ...	2.8	2.8	0.6	3.4
Hulls	13.2	—	13.8	13.8
Meats	75.5	—	75.3	75.3
	100.1			99.7

TABLE IV

Power Consumption for Cutting Linters

Weight of seeds lb.	Linter cut First lb.	Linter cut Second lb.	Linter cut Total lb.	Power First KWH	Power Second KWH	Power Total KWH	Power per lb. of linters KWH
1174	63.2	—	63.2	28.8	—	28.8	0.456
2940	82.0	37.0	119.0	31.5	47.0	78.5	0.660

TABLE V

Processing Data & Costing

			%
Materials processed	54,810	kg.	–
Meats	32,702	,,	59.7
Hulls	18,070	,,	32.0
Linters	2,018	,,	3.6
Oversize	156	,,	0.3
Cotton dust	578	,,	1.1
Dust (earth)	1,131	,,	2.1
Loss	155	,,	0.3
Total	54,810	kg.	100.0

(Contd.)

TABLE V *(Contd.)*

			Rs. nP.
Direct Costs			
1. *Power*			
For delinting	3186 units		
For hulling	548 ,,		
For lights	234 ,,		
For filing & gumming	12 ,,		
	3980 units at Rs. 0.10 per unit		398-00
2. *Supervision & labour*			
One assistant at Rs. 6.00 per day			
Three foremen at Rs. 6.00 per day			
Twelve labour at Rs. 1.28 per day			
Actual amount paid			997-84
. *Repairs & replacements*			
Files 5	Rs. 20.00		
Sidefiles 2	Rs. 8.00		
Saws 4	Rs. 22.00		
	Rs. 50.00		50-00
4. *Lubrication*			
Grease and oil			16-00
5. *Miscellaneous & sundries*			
(*i*) Rosin Cottonwaste Graphite Belt screws Belt clips Ball bearing spanner Brooms, etc.			41-25
(*ii*) *Proportionate cost of belts*			
(*a*) Leather belt (*b*) Hair belt			28-48
Indirect Costs			
6. *Insurance* on machinery at 1% for 29 days			79-44
7. *Depreciation*			
(*a*) On delinting machinery for 68 shifts at 10%		383-33	
(*b*) On hulling machinery for 13 shifts at 10%		83-33	
(*c*) On building for 29 days at 5%		397-26	863-92
		Total	2,474-93
8. *Royalty* to Laboratory, 10% total bill			247-49
		Total	2,722-42

Cost for processing per ton ... Rs. 49.60

processing arrangement, so that the delinted seed were subjected to hulling and separation into hulls and meats *i.e.* "mill-run."

Two more batches of about a ton each of cottonseed were delinted to cut about 2.5% of linters and the delinted seeds were subjected to further delinting to obtain maximum linters without damaging the seeds.

The average percentage yields of various products obtained in both adjustments are shown in Table III. It is seen that the yield of linters is higher using the mill-run adjustment, although the quality of linters, by first-cut (ash content 2.99%) is superior to that of the mill-run (ash content 4.27%).

The average power consumption for cutting a unit pound of linters by mill-run, and by first-cut followed by second-cut, is shown in Table IV; this indicates that the power is lower for the mill-run than for the other. The high power consumption in the latter is compensated by obtaining a part of the linters of superior quality. If there is a good demand for first-cut linters at a price which will compensate for the extra power consumed, it is advantageous to produce linters in two cuts.

Continuous Processing

In collaboration with a local firm, 54 tons of a commercial mixed variety of cottonseed containing 80% American variety and 20% *desi* variety, were processed continuously in the pilot-plant, working three shifts per day. The adjustment made was for the mill-run, and the yields of various products, the power consumed, labour and other requirements were noted and the costing was done for processing, which is shown in Table V. It is seen that the processing cost works out to about Rs. 50 per ton.

It may be pointed out that all the units in the pilot-plant have capacities of about 25-30 tons per day, but the delinter has a capacity of only 3.5-5 tons. The processing had to be adjusted according to the capacity of the delinter. If the number of delinting units are increased to raise the capacity to 25 tons per day, the processing costs will be considerably reduced.

Acknowledgment

The authors wish to acknowledge with sincere thanks the help rendered by Shri G. S. Chowdhury during the erection of the pilot-plant. Thanks are also due to Shri Waris Baig for his assistance in the collection of data during the continuous processing of the cottonseed.

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2. HIGH-CAPACITY EXPELLER OPERATIONS IN THE PROCESSING OF COTTONSEED

By
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A study of the results in processing cottonseed in Anderson Super Duo Expellers showed that capacity could be further increased while maintaining efficiency by correct preparation of meats, correct and matched R.P.M. in both shafts, and proper worm arrangement. This was practically achieved at capacities of 50 tons per day. The new Expeller 55 developed by Anderson crushed even higher capacities, with 3% or less residual oil in cake on a 41% protein basis.

In 1952 at the American Oil Chemists' Society meeting we reported initial results obtained when speeding up the Anderson Super Duo Expellers for the processing of cottonseed meats.[1] At that time we had commercial results, which proved that each machine was capable of processing the meats from 50 tons per day of cottonseed and obtaining residual oils in the meal between 4 and 4.5%.

It was recognized at the same time that the preparation of the raw material was highly important in order to obtain the capacities and efficiencies outlined above. In the preparation of the cottonseed for this high-capacity Expeller operation the seed was delinted, decorticated and the meats separated from the hull. The meats were then humidified to approximately 10% moisture and passed to Cooker-Dryer units where they were cooked at a temperature of approximately 195°F. for a period of 15 minutes. During the cooking operation, the moisture was maintained at approximately 12%. This accomplished coagulation of the protein in the cottonseed meats,[2] as well as detoxifying the gossypol. After the meats were properly cooked they were dried to 3% moisture and fed to the Expeller.

These first results when analysed from a mechanical engineering standpoint, gave us the principle that capacity could be increased while still maintaining efficiency under the following conditions:

(1) Correct preparation of the raw material to be passed.
(2) Correct RPM and relationship of RPM of the vertical and main worm shafts.
(3) Proper selection of the arrangement of the worms of the two shafts.

By applying these principles to commercial operations from 1952 through 1956, it was possible to maintain the capacity of the Expellers at the stated 50 tons per day while at the same time decreasing the residual oil in the produced cake. For example, a U.S. mill operating their two Super Duo Expellers at 52 RPM on the horizontal shaft and 104 RPM on the vertical shaft, using a YNV-3 main worm shaft arrangement, processed the meats from 55-57 tons of cottonseed per day. At an average of 56 tons of seed per day per Expeller they obtained oil in the cake from 3.2 to 3.6% on a 41% protein basis. A second mill operating in the Republic of Mexico, operates three Super Duo Expellers. This particular mill is equipped with sufficient preparation equipment to adequately delint, decorticate, separate, cook and dry approximately 100 tons per day of cottonseed. The separation equipment is adequate to produce approximately 45-46% protein in the final cake. They have adjusted their Expellers to operate at 32 RPM on the horizontal shaft and 70 RPM on the vertical shaft and they use a YNV-3 arrangement for the main worm shaft. Each Expeller normally presses the meats from 30-35 tons per day of cottonseed. The cake discharging from the Expellers, over a three month period, averaged 3.1% oil with 45.6% protein. On a 41% protein basis, the oil in cake ranged from 2.4 to 2.9% representing a standard of less than 35.

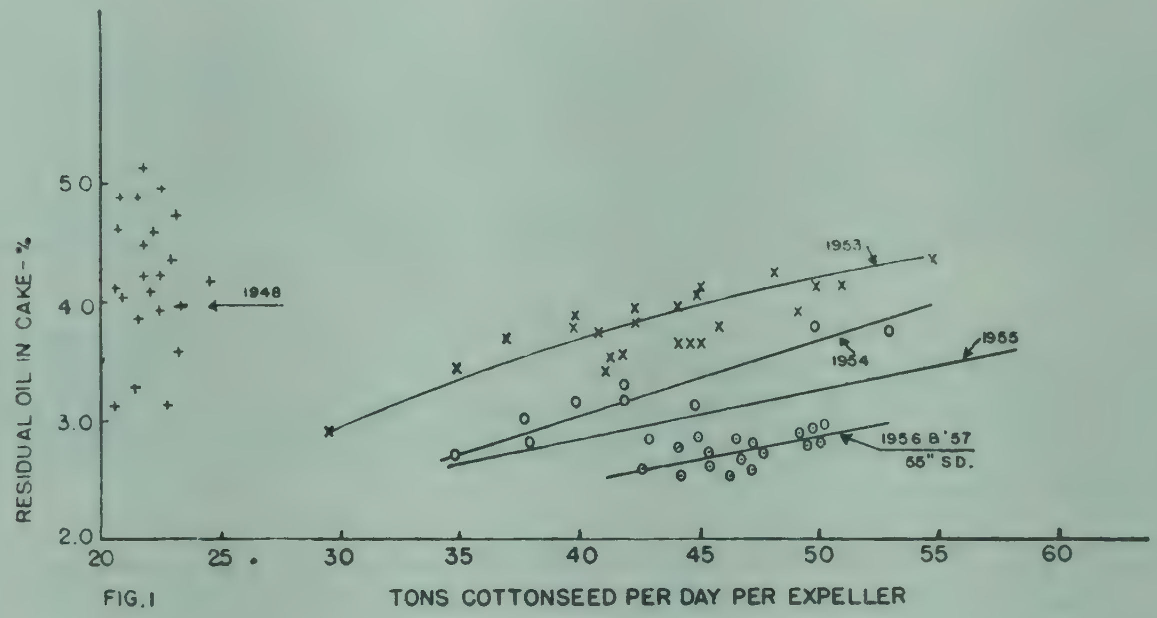

FIG. I

Referring to Fig. 1, you will notice the progress that has been made in the processing of cottonseed from 1948 through 1957. The capacity in 1948 averaged between 20 and 25 tons per Expeller with residual oils ranging from 3.1 to 5.1%. With the development of the High Capacity Process, Expeller capacities have been increased to as high as 55 tons per machine and residual oil has been lowered below 3%. All the above figures are calculated on a 41% protein basis.

In 1956 the V.D. Anderson Company embarked on a programme of research and development to increase the efficiencies of their Expeller. Since one of the primary raw materials in the United States is cottonseed, all tests with the new machine were carried out on this material. Because of the work in the cottonseed field in which we had co-operated from 1953 through 1957, we knew that capacity could be obtained rather easily by simply speeding up both of the shafts of an Expeller. The factors that were necessary to maintain low residual oils and higher pressures were difficult to accurately ascertain, particularly in view of the difference in protein content of the many different vegetable oilseeds processed in Anderson Expellers. It was our belief that simple modifications or additions, such as speeding up the shafts of our present machines, were not the answer to our objective. We believed it would be necessary to design and fabricate a larger, new Expeller. With the co-operation of a number of commercial mills, an Expeller, which was designed and fabricated for this specific object, was put into commercial operation in the field. The new Expeller basic casting was lengthened so that it would contain a 55 inch long horizontal barrel. The design of the arrangement of worms on the main worm shaft was changed to obtain greater pressure with a subsequent higher pressing efficiency. For the longer retention time at higher pressures, it was necessary to increase the horsepower of both the vertical and horizontal pressing shafts. We maintained the RPM of both the shafts at approximately the same figures as those used for the standard Super Duo Expellers using the High Capacity Process, although we believe these can be increased in the future.

The results from the first mill that went into operation with this unit were very gratifying. Using one Expeller, a capacity of 48 tons per day of cottonseed was processed. Separation equipment was adequate to produce meats that resulted in cake containing approximately 47% protein. The residual oil in the meal on a 41% protein basis averaged 2.94% in the very first week of operation. Another mill that had installed two of the newly-designed Expellers proved an even better operation. Rolling, cooking and drying was accomplished following the usual procedures, no special treatment being given to the meats during these operations. Separation of the hulls at this mill resulted in cake of approximately 47% protein. The capacity averaged 99 tons per day over a period of 45 days. The standard of operation for these 45 days was 36, or slightly under 3% residual oil on a 41% protein basis.

A third mill installed three of these Expeller units. They are processing 150 tons per day. Because of limitations in their separation equipment, the protein in the cake ranged from 43 to 49% in a period of 8 days. The average residual oil, however, for these 8 days was 2.88% on a 41% protein basis at 50 tons of seed per day per Expeller.

It must be kept in mind that carefully-controlled preparation of the raw material, including cooking and drying, is a definite pre-requisite for obtaining the capacities and efficiencies outlined above. To obtain good operation, the seed must be delinted, decorticated and the meats separated from the hull. A complete separation of the meats from the hull is not required, but based on commercial mill reports we believe that sufficient hull should be separated to produce a cake from the Expeller containing no less than 45% protein.

In many mills the cleaned meats are conditioned in order to increase the moisture content to 10% and to raise the temperature slightly before rolling. Rolling of cottonseed meats permits more complete cooking and facilitates quick drying after cooking. The rolling of the meats is carried out most efficiently in a two roll, single pass unit, forming 0.010-inch thick flakes. These flakes are then passed to the cooker and, as described previously, the cooking is carried out at a temperature of 195° F., at a moisture of 12%, for a period of time of 15 to 20 minutes. The additional moisture to bring the level of moisture up to 12% in the cooker is normally added to the meats by means of direct sparge steam in the cooking vessel itself. The heat from this same steam generally permits the jacket pressure of the vessel to be maintained at 30 PSIG. The drying should be accomplished as quickly as possible, since cottonseed oil is heat sensitive. Prolonging the drying cycle will definitely degradate the oil by increasing the free fatty acid, at the same time darkening it to the point that it is not economically feasible to attempt to bleach out this colour.

The above conditions for cooking govern most cottonseed processing, but are pertinent to the processing of prime quality cottonseed having a fairly low free fatty acid. Special procedures for cooking must be carried out when the original seed has either been burned or contains a high percentage of free fatty acid.[3]

Following the above controlled procedures, the Expeller 55s developed by the V.D. Anderson Company are today operating at averages of 50 tons per day capacity and producing residual oils of 3% or less. Since the conception of the High Capacity Expeller Process in the United States, approximately fifty mills have installed High Capacity Units, and since 1957, nine mills are operating Super Duo 55-inch Expellers.

As a note of general information, the High Capacity Expeller Process, as well as the newly developed 55-inch Expeller, has proved commercially applicable to other vegetable oil processing requirements. As an example of this, in processing peanut kernels, the Expeller 55 has a capacity of 45 to 50 tons per day with residual oils ranging between 3.1 and 3.5%.

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3. PROCESSING OF COTTONSEED

By
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Frankfurt-am-Main, Germany

Lurgi processes and equipment for expelling of cottonseed, direct solvent-extraction of cottonseed, refining of cottonseed oil, deodorization, hydrogenation and soapstock distillation are described.

Introduction

Apart from soyabeans, cottonseed is of great importance for the production of edible oil. Owing to the evolution in the methods of oil production one is in a position today to obtain an excellent edible oil from cottonseed. The residues from this modern method of production are utilized as a provender. Generally they are mixed with other oilseed residues, or other kinds of feed are added to it, in which way the well-known mixed provender is obtained.

Processing of Seed

Cottonseed has an oil content of 18-25% depending on its properties. The oil content of the dehulled seed is 30-40%. Delinting is usually carried out directly on the farm or in cotton spinning mills. Care should be taken that the cottonseed is thoroughly delinted because a high content of linters in the entering material results in the seed swelling up which may easily cause clogging during the subsequent treatment of the seed.

The mechanical arrangement of an oil factory is shown in the general layout in Lurgi pamphlet LWP-DO 10e. The arrangement of a cotton oil factory is roughly identical with a soya oil factory as may be seen from Fig. 1.

Cottonseed is supplied by ship, rail or truck, depending on the situation of the oil factory. Silos are available to take up larger quantities of seed. From these silos the seed is withdrawn by continuous operation and dehulled in the dehulling unit which is usually located within the silo building or in the building of the preparatory unit of the pressing plant. Cottonseed hulls are often utilized for heating purposes and conveyed to the boiler-house. During dehulling a certain portion of hulls is retained and fed to the oil-producing unit together with the seed kernels. The protein content in the residue is thereby slightly reduced but the treatment of the oilseed facilitated.

The dehulled seed is heated, then crushed in fluted or plain roller mills and subsequently prepressed from 30-40% to approximately 20% oil content by means of expeller presses. The expeller cake is once more crushed and then fed to the extractor where the oil is extracted out of the cake by means of solvent. In this way a residual oil content of 0.25% is reached in the extracted material, *i.e.*, in the residue.

Solvent Extraction

By further development of our new Lurgi extraction plant with horizontal extractor we are now in a position to directly solvent extract, without any prepressing, oil-rich seeds to which cottonseed also belongs. In the case of direct extraction, the seed after crushing in fluted and plain roller mills is directly fed to the extractor and the oil extracted there by means of solvent. With this direct extraction, residual oil contents of approximately 0.6% are achieved in the extracted material or residue. In this new method developed by us the pressing operation is omitted which means a simplification of the plant as a whole and better economy owing to the special features of the Lurgi extraction process. The general arrangement of such a Lurgi extraction plant is shown in Fig. 2.

The meal deoiled by means of solvent still contains about 30% solvent when leaving the extractor. This solvent is driven out of the extracted material by indirect and direct steam. The ensuing solvent/water vapours which also still carry a certain amount of meal particles are exposed to thorough scrubbing and the purified vapours can then be utilized for heating, *e.g.*, of the oil desolventizer. This assures good economy of the extraction plant because compared to the customary extraction plants the steam consumption is considerably lower. With large-size plants steam consumption figures as low as 250 kg./ton of seed are the rule.

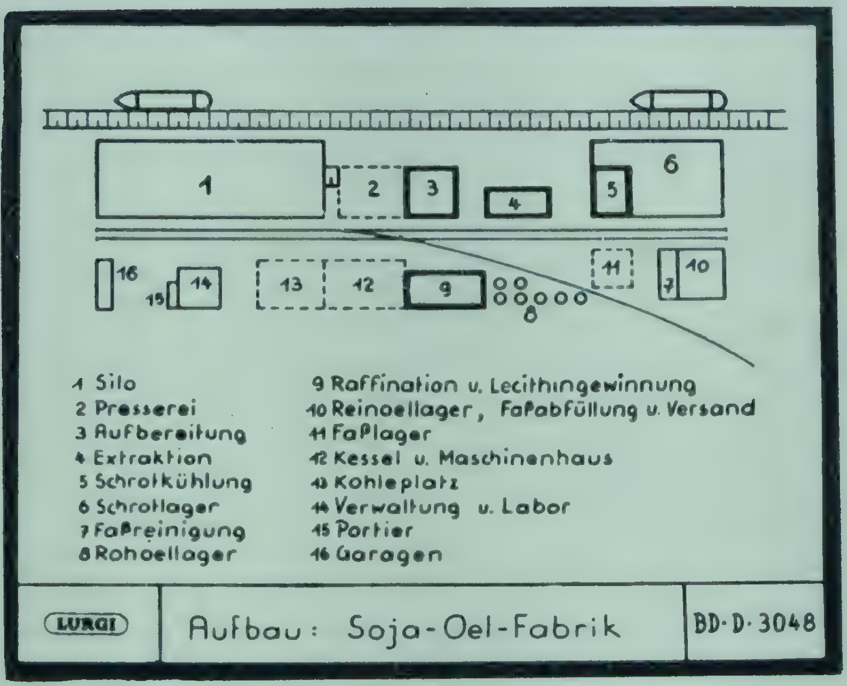
Due to the introduction of direct steam and the boiling of the residue the gossypol contained in the material is destroyed so that the residue may be used as cattlefeed.

The residue leaving the extraction has usually a temperature of approximately 105°C. Such a high temperature does not permit storage and for this reason a residue-cooling unit has always to be combined with the extraction plant if no extremely long transport distance to the storehouse prevails. Our newly-developed Lurgi cooling method is most suited for the cooling of the residue, and has in fact proved excellent in practice, the residue being cooled to a temperature of approximately 10°C above the outside air temperature. If storage bunkers are provided, this cooling equipment is usually arranged above the bunkers. The residue itself is weighed by a weighing machine and bagged. The general layout of such a unit is shown in Fig. 3.

During the extraction by means of solvent a solvent/oil mixture is obtained called miscella. The new Lurgi process is capable of operating at high miscella concentration so that in this way also the economy of the plant is favourably influenced to a large extent. This miscella is passed to an oil desolventizer working under vacuum. Here the solvent is evaporated with careful thermal treatment of the oil. The solvent vapours are passed to a condenser and the resulting solvent led through a solvent/water separator and returned to the top of the extractor for re-use in deoiling the seed. The oil itself is once more treated with direct steam in the distillation column during which procedure a certain pre-deodorization of the oil takes place. The extracted crude oil is pumped to a vacuum receiver and from there on to the refining plant. If a pressing unit is incorporated in the factory, the extracted oil is mixed with the pressed oil and both fed to the refinery as mixed oil.

Refining of Oil

The crude cottonseed oil has a dark red colour and contains a number of impurities, such as lecithin, free fatty acids, protein, gum colour, odour and flavour bodies which must


1
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1 Silo
2 Presserei
3 Aufbereitung
4 Extraktion
5 Schrotkühlung
6 Schrotlager
7 Faßreinigung
8 Rohoellager
9 Raffination u. Lecithingewinnung
10 Reinoellager, Faßabfüllung u. Versand
11 Faßlager
12 Kessel u. Maschinenhaus
13 Kohleplatz
14 Verwaltung u. Labor
15 Portier
16 Garagen
LURGI
Aufbau: Soja-Oel-Fabrik
BD·D·3048

Fig. 1

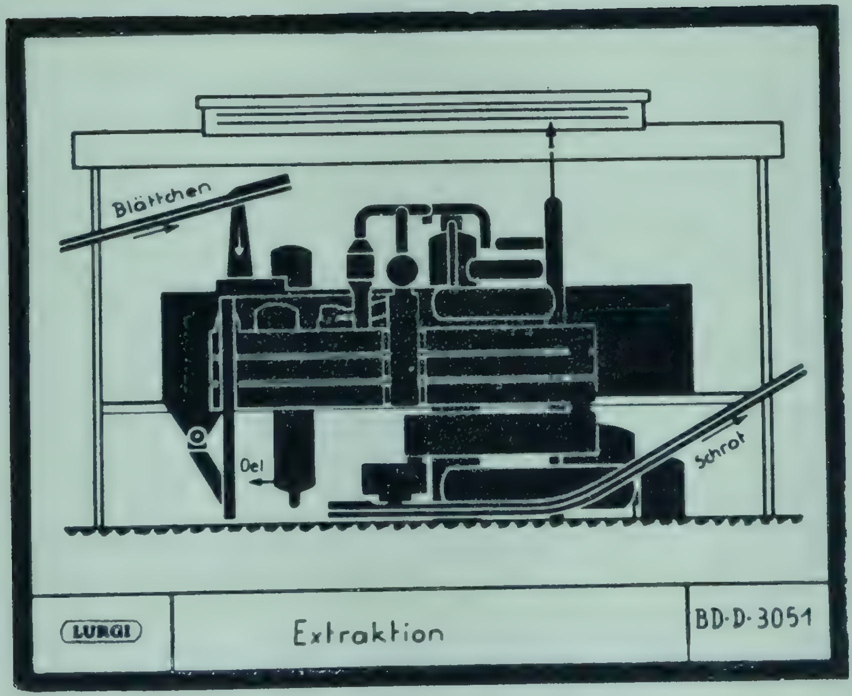
Blättchen
Oel
Schrot
LURGI
Extraktion
BD·D·3051

Fig. 2

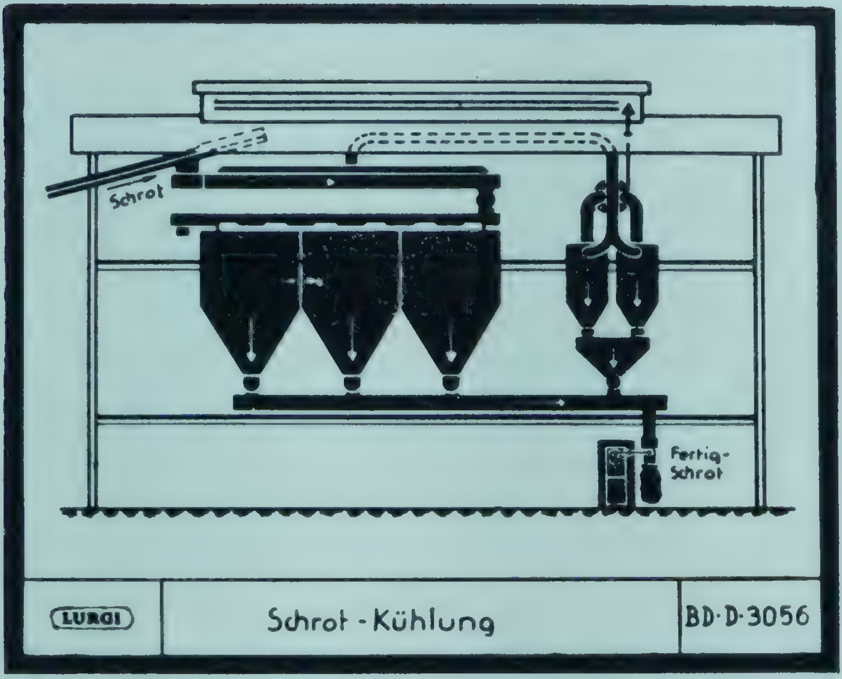
Schrot
Fertig-Schrot
LURGI
Schrot-Kühlung
BD·D·3056

Fig. 3

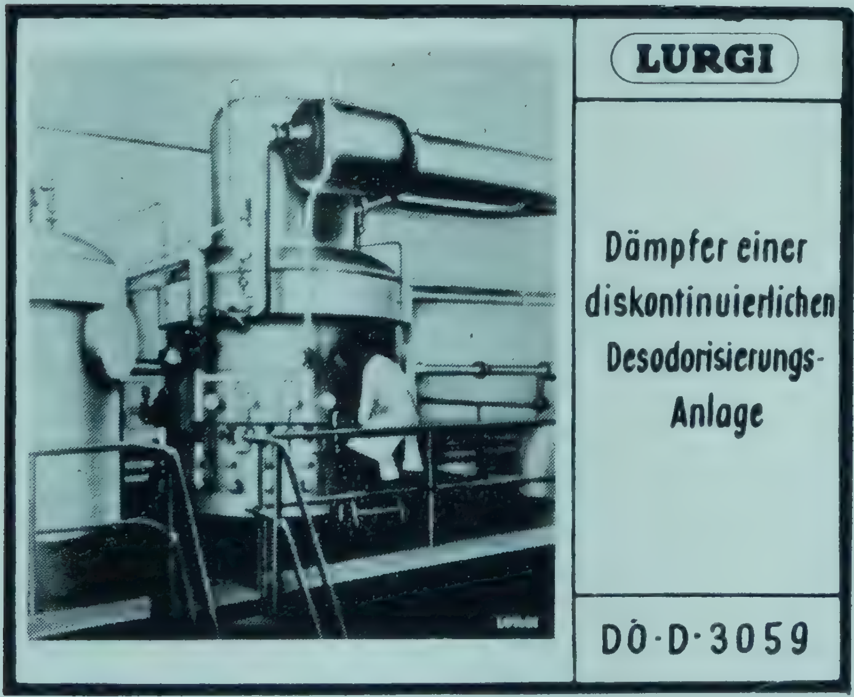
LURGI
Dämpfer einer diskontinuierlichen Desodorisierungs-Anlage
DÖ·D·3059
LURGI

Fig. 4

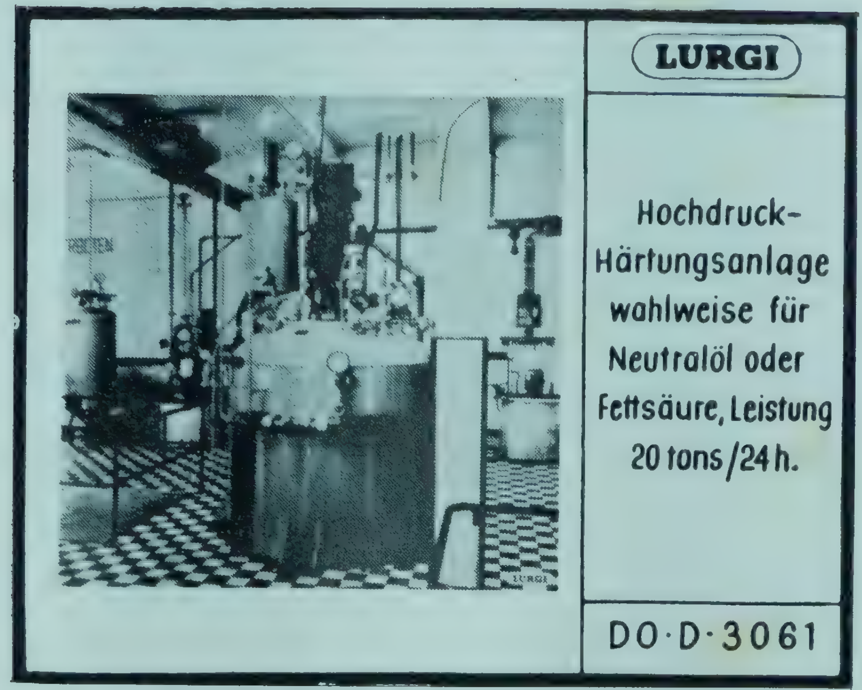
LURGI
Hochdruck-Härtungsanlage wahlweise für Neutralöl oder Fettsäure, Leistung 20 tons/24 h.
DO·D·3061

Fig.5

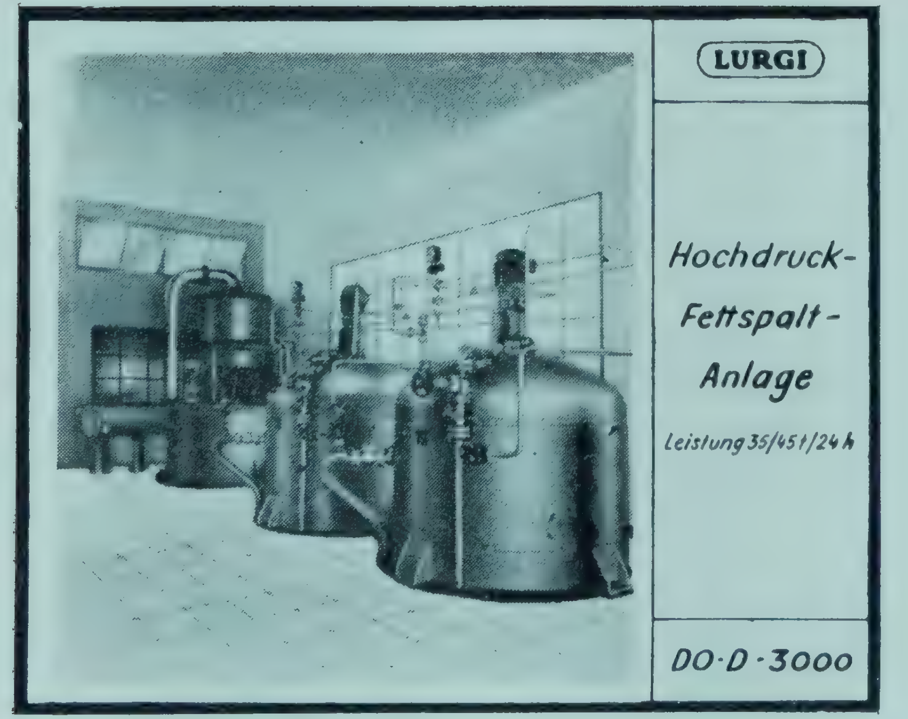
LURGI
Hochdruck-Fettspalt-Anlage
Leistung 35/45 t/24 h
DO·D·3000

Fig. 6

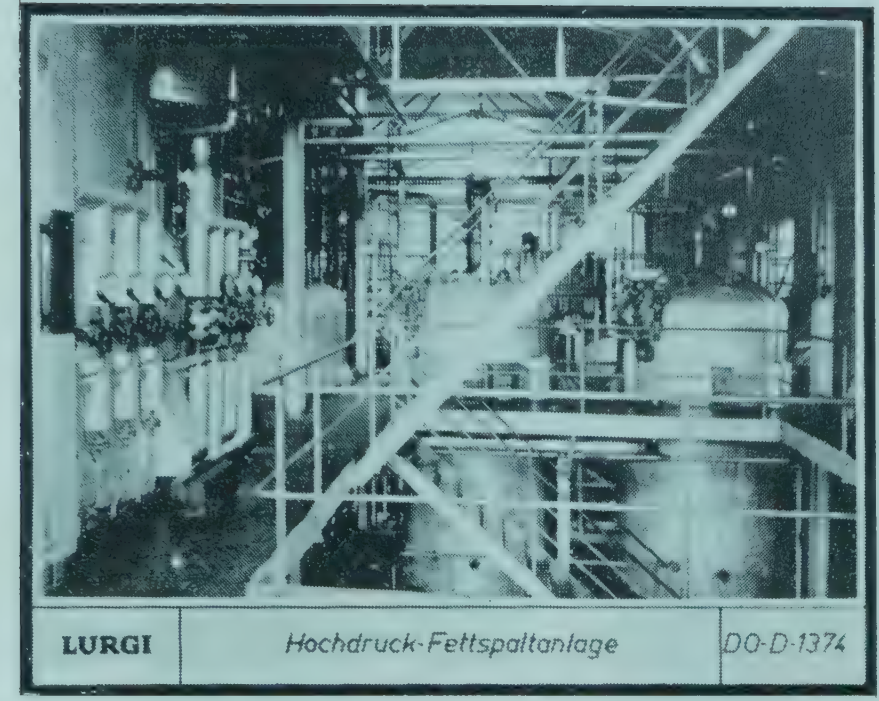
LURGI
Hochdruck-Fettspaltanlage
DO-D-1374

Fig. 7

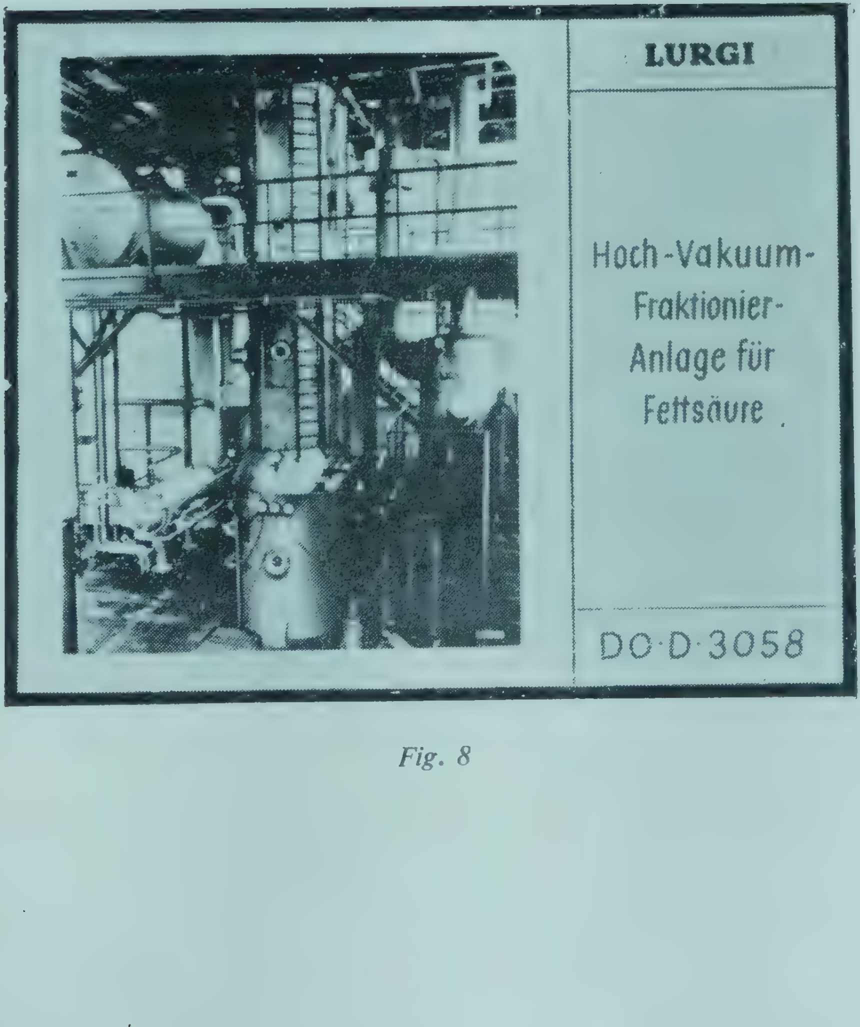
LURGI
Hoch-Vakuum-Fraktionier-Anlage für Fettsäure
DO-D-3058

Fig. 8

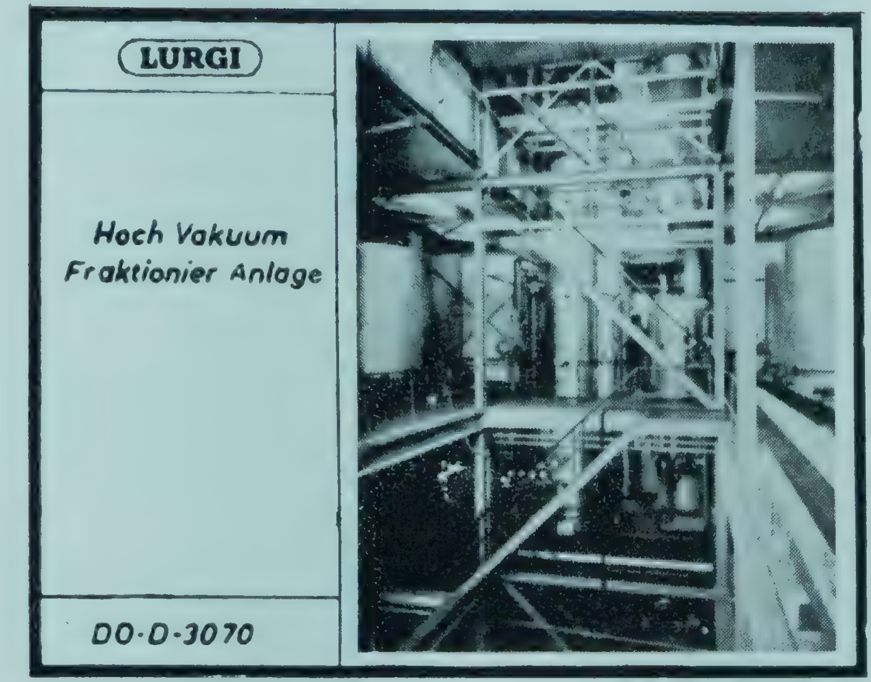
LURGI
Hoch Vakuum
Fraktionier Anlage
DO·D·3070

Fig. 9

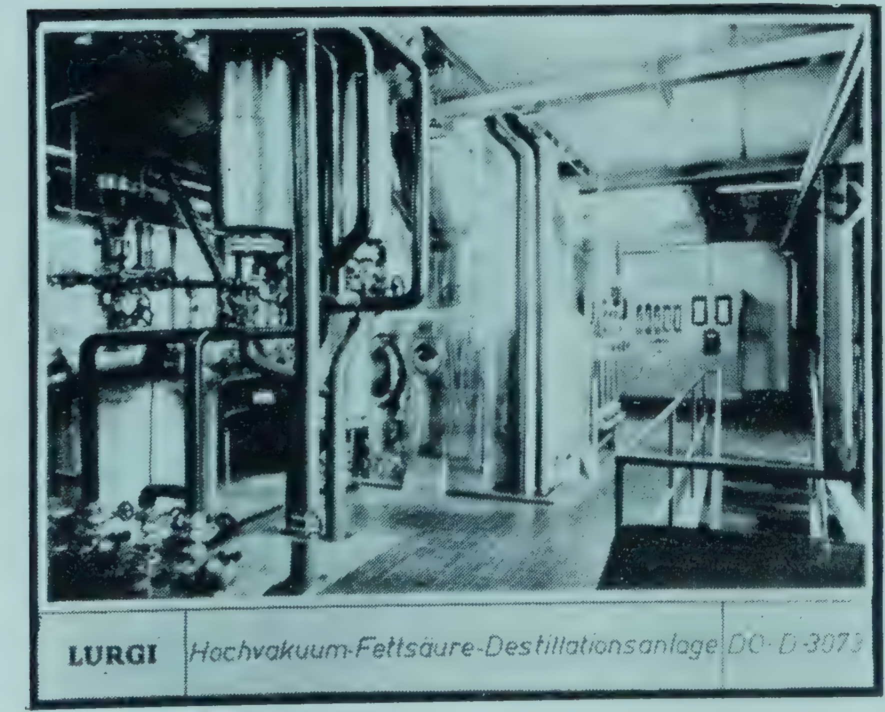
LURGI
Hochvakuum-Fettsäure-Destillationsanlage
DO·D·3073

Fig. 10

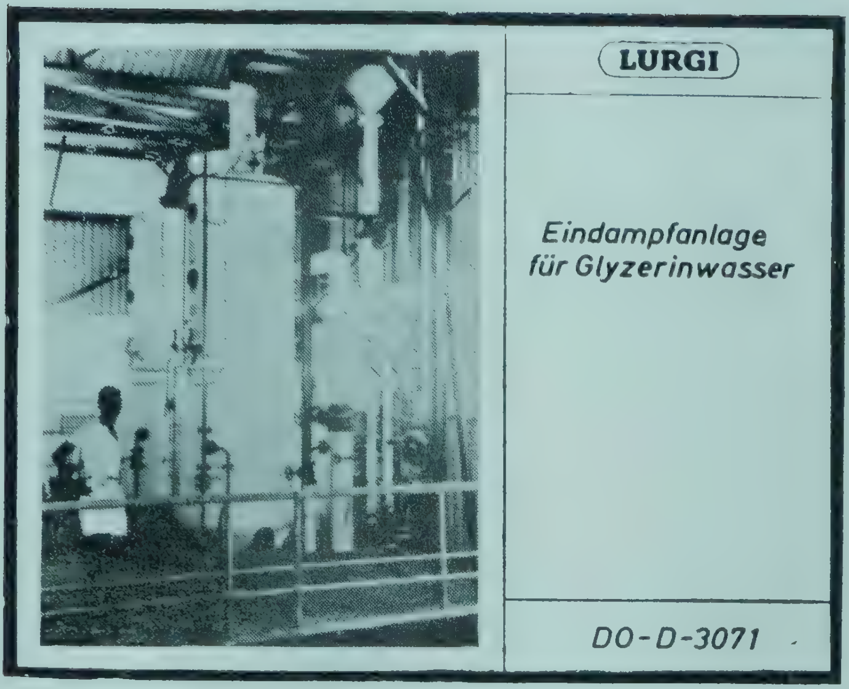
LURGI
Eindampfanlage für Glyzerinwasser
DO-D-3071

Fig. 11

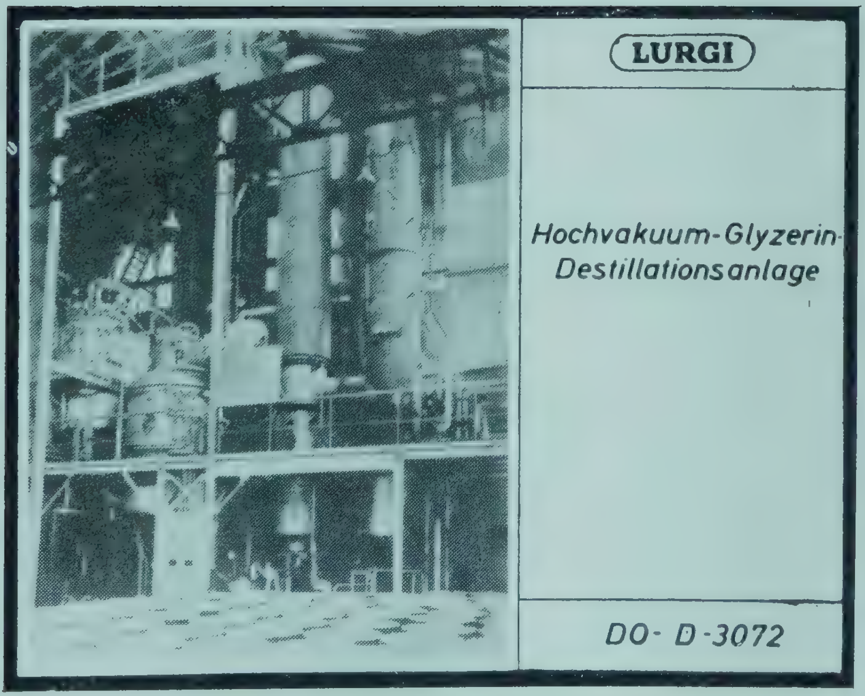
LURGI
Hochvakuum-Glyzerin-Destillationsanlage
DO- D-3072

Fig. 12

all be eliminated in order to be able to use cottonseed oil as an edible oil. The separation of these impurities is carried out one after the other in individual oil-refining stages.

The lecithin is eliminated after swelling with hot water in sludge separators, in continuous operation. The yield is low and the quality of the cotton lecithin so bad that in most cases the production of cotton lecithin has been dropped. The elimination of the lecithin falls to the second refining stage, *viz.*, pre-purification, where the coagulable impurities of cotton oil, such as proteins and gums, are separated by the action of mineral acids and acid salts. They form flaky substances which are separated by decantation. The mineral acid solution or salt solution utilized for the pre-purification can, after replenishing the spent mineral acid, be employed several times over. The gum cake containing relatively little oil is however rejected.

In the next stage of oil refining the free fatty acids of the cotton oil are separated as soda soap by addition of soda lye. This is the most important part of the oil treatment during which 1 to 7% of the oil has to be separated, being the percentage of free fatty acids precipitated as soap flakes. In order to force a major part of the gossypol pigment to separate together with the soapstock, it is necessary to provide for a considerable excess amount of soda lye during neutralization. The unavoidable consequence of this measure is the formation of soap from neutral oil which has the effect of reducing the yield. If a process is applied such as proposed by Lurgi, featuring employment of sodium carbonate together with the soda lye and operation under vacuum, these refining losses are greatly reduced. Separation of the soapstock, which even in the most favourable case still contains neutral oil, is carried out by way of decantation in conical receivers or by separators. The last traces of soap flakes are eliminated by washing with hot water and then the oil dried under vacuum is bleached with fuller's earth at 80-110°C. After cooling the oil to 30-40 °C. the fuller's earth is removed by filtration and in the deodorizer that follows oil is finally treated with open steam under high vacuum at a temperature of 180°C. for four hours, when all flavour and odour bodies are completely eliminated. If a higher deodorizing temperature, *e.g.*, 230°C. is chosen, the steaming periods are reduced and the colour of the oil even slightly brightens. Fig. 4 shows a deodorizing plant.

Hydrogenation to Edible Products

Cotton oil is especially suitable for the production of fats substituting for butter. One obtains a pasty fat that can be spread, by addition of hydrogen at the double bonds of the unsaturated fatty acids existing in cotton oil. This fat can at the same time be used as baking and cooking fat. The cotton oil hardened at increased pressure and 150-200°C. in agitator autoclaves has to be post-refined and in most cases to be also post-bleached before deodorization. Fig. 5 shows an oil-hardening plant, which is preferably used for neutral oils or fatty acids, of capacity 20 tons/24 hrs.

Soapstock Utilisation

The soapstock derived from oil neutralization, which always contains some neutral oil and therefore glycerine, is transformed to distilled fatty acid or fatty acid fractions and glycerine. On decomposition of the soapstock by means of dilute sulphuric acid and separation of the impurities thereby precipitated, the crude fatty acid obtained is passed into high pressure splitting autoclaves for hydrolysis, *i.e.*, splitting with water. At a temperature of 225° C. and in fully-continuous operation, these autoclaves, working on the countercurrent principle, produce from the soapstock fatty acid split water containing glycerine and a split fatty acid with more than 95% free fatty acid. By distillation of the split fatty acid in high vacuum one obtains pure white distilled fatty acids which can be processed to laundry or even toilet soaps. Sometimes it is advisable to distil twice and to blow the primary distillate at 90° C. with air in order to convert the volatile remainder of the gossypol pigment into an undistillable state by oxidation. As cotton fatty acid contains more than 20% palmitic acid which is in great demand by the chemical industry, it is recommended that the cotton fatty acid be resolved by fractional distillation into a top fraction (*i.e.*, palmitic acid) and a bottom fraction mainly consisting of linoleic and oleic acids. The latter fraction is preferably employed for the production of soft soap and of aldehyde resins.

Complete Hydrogenation

A further possibility of processing cotton fatty acid is by total saturation with hydrogen. The mixture of palmitic and stearic acids thereby obtained furnishes, possibly after spraying, a product much in demand by the chemical industry. Figs. 6 & 7 show the Splitting Plant; Figs. 8 & 9 the Fatty Acid Fractionating Plant; and Fig. 10 the Fatty Acid Distillation Plant.

Glycerine Recovery

The glycerine-containing split water is pre-purified with mineral acid and aluminium salts, then concentrated to about 90% and subsequently distilled under high vacuum. After treatment with a small quantity of fuller's earth the resulting distillate constitutes a pure glycerine suitable for pharmaceutical purposes. An ion exchanger included before the evaporation plant will completely eliminate all mineral matter and all pigments from the split water, yielding a colourless and pure glycerine even without distillation. Fig. 11 shows a Sweet Water Evaporation Plant, and Fig. 12 a Glycerine Distillation Plant.

4. STORAGE OF COTTONSEED AND ITS OIL

By

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In cottonseed storage, moisture content of seed is almost wholly regulated by external relative humidity. A seed moisture level of about 10% (70% R.H.) is critical for cottonseed, above which the seed of F.F.A. rises and colour is fixed. Mechanical damage hastens seed deterioration, and wetting is disastrous. Storage of seed in loose pyramidal heaps is recommended. Crude cottonseed oil is extremely stable, but colour fixation occurs to a marked degree; even refined oils are fairly stable both in regard to F.F.A. and to colour. Recommendations are made for storage of seed and oil.

Introduction

Cottonseed is unique among oilseeds in its high degree of pigmentation and the sensitivity of these pigments to air, light and moisture. The changes in the seed, which affect the colour, refinability and bleachability of the subsequently-expressed cottonseed oil, are largely dependent upon the conditions of seed storage. The large amount of work on cottonseed storage in the U.S.A. has been admirably covered till about 1946 by Boatner and Altschul.[1] Some of the salient observations are summarised here:

1. Field-damaged seeds, usually rain-occasioned and recognised by a prime colour, yield a lighter oil than storage-damaged seeds which are usually discoloured.

2. The heating observed in stored cottonseed is stimulated by a seed moisture content of over 10% (which in turn is dependent on the external humidity), by storage in bulk of over about 3 tons, by insufficient aeration, and by the presence of pentosan-rich materials like bolls, stalks, etc. Such heating destroys the viability or germinating power of the seed, lowers the grade of lint and its fibre strength and results in seed oil of high colour and free fatty acidity (FFA), and of poor refining characteristics.

3. Lipase activity in seed, resulting in free acid release in seed oil, proceeds at an increased rate with seed storage. High moisture, temperature and initial FFA stimulate the rate of lipolysis.

4. The higher the FFA of seed oils, the poorer is the germination of seed; 1% FFA is a safe limit.

5. Each cottonseed species *e.g., Gossypium hirsutum, Gossypium herbaceum*, etc., contains a characteristic content of pigments, mainly gossypol and gossypurpurin.

6. The patterns of respiration and pigment development in immature or "bollie" cottonseed are different from those in mature seed.

7. Seed deterioration during storage can be minimised by prevention of wetting, pre-drying, aeration with dry and cool air, treatment with ammonia or ethylene chlorhydrin, and storage and processing in order of decreasing FFA content.

A survey of commercial storage practices by personal visits to cottonseed areas around Hyderabad, indicated that the seed was stored from 2-3 weeks to as long as 6 months, either in gunny bags or in heaps in various ways—in the open (bare or tarpaulin-covered), in mounds or in covered sheds. These practices often resulted in heating with ensuing discolouration of the seeds and meats, and subsequent deterioration in the quality of the oil. There was practically no effort to grade the seed.

Results of detailed studies on the effects of storage of cottonseed and its oil, published elsewhere[2,3,4] are summarised in this paper.

Storage of Cottonseed

Data obtained by storage of cottonseed under accurately-controlled temperature and relative humidity (R.H.) show that the moisture of cottonseed, irrespective of variety, is flexible and almost wholly regulated by external humidity. American Parbhani cottonseed stored at 65, and 80 and 85% R.H. show moisture contents of 9.2, 13.6 and 15% after 35, 37 and 35 days respectively (Table I).

TABLE I

Controlled Temperature-Humidity Storage of American Parbhani Cottonseed

At 85% R. H. and 40°C.				At 65% R. H. and 33°C.				At 80% R. H. and 33°C.			
Days	M%	F%	V%	Days	M%	F%	V%	Days	M%	F%	V%
0	6.4	1.1	100	0	8.3	2.0	100	0	8.2	3.0	100
1	11.1	...	...	6	11.8	2.7	...	1	11.1	...	...
8	14.2	2.3	...	8	10.1	...	...	4	13.4	...	...
10	14.1	...	...	14	...	2.6	...	37	13.6	10.8	0
11	14.8	2.3	...	29	...	2.9	...	50	13.4	12.8	...
17	14.8	6.3	...	35	9.2	...	...				
21	14.9	6.6	...	55	...	3.0	...				
26	15.2	9.0	...	70	8.4	...	...				
35	15.0	15.1	...	90	10.0	4.0	40				
75	...	25.6	...								
90	...	29.8	0								

(M=Moisture in seed. F=Free fatty acids in seed oil. V=Viability.)

At a constant R.H. the percentage moisture in the seed reaches a constant value — the equilibrium moisture content. Thus the moisture contents after 20 days storage at 80% R.H. and 33°C. for different cottonseeds are similar at 14-15% (Table II).

TABLE II

Controlled Temperature-Humidity Storage of Six Standard Cottonseeds

	CO_4/ B-40		Jayadhar		2087		K_2		MU-1		Gaorani-6	
Days	M%	F%	M%	F%	M%	F%	M%	F%	M%	F%	M%	F%
A. At 80% R. H. and 33° C.												
0	9.2	2.7	9.6	2.5	8.9	3.1	11.0	2.5	9.2	0.6	9.6	2.6
1	10.3	...	9.6	...	9.6	...	11.1	...	9.9	...	10.6	...
5	11.7	...	13.3	...	13.0	...	13.7	...	12.9	...	12.1	...
7	13.8	...	13.7	...	13.7	...	14.2	...	12.9	...	13.7	...
20	14.2	5.4	14.7	3.3	14.4	3.7	14.4	5.7	13.9	2.9	14.0	5.2
B. At 65% R. H. and 35° C.												
0	10.5	2.3	11.4	2.6	10.9	3.2	10.8	2.6	11.9	2.0	9.5	3.0
1	10.1	...	10.6	...	10.7	...	10.7	...	11.2	...	10.3	...
4	9.3	...	11.1	...	9.6	...	10.0	...	11.3	...	9.8	...
15	9.0	...	10.8	2.9	9.2	...	9.6	...	10.7	...	9.2	...
45	8.5	2.5	9.2	...	8.5	3.5	9.2	3.7	10.2	2.3	8.1	3.2

(M=Moisture in seeds. F=Free fatty acids in seed oil.)

An equilibrium moisture level of about 10% (corresponding to about 70% R.H.) appears to be critical for cottonseed. Below this level, *i.e.*, when the seed is stored at lower R.H. or if the seed is pre-dried and kept in air-tight tins (Tables I, II, IIIA), the seed can be stored for fairly long periods, without any great loss in viability or increase in free fatty acids. There is however a definite fixation of colour in the seed oil during seed storage resulting in decreased refinability and bleachability (Table IV). Thus in 5 months of storage in gunny bags of American Parbhani seed with seed moisture less than 10%, the bleach colour of the seed oil increased from 6.6 to 15 units (Y+10R).

At higher humidities, rapid moisture equilibration occurs in the seed within 24 hours, FFA in the seed oil increases rapidly and seed viability is lost. At 85% R.H. for example, FFA increase in the seed oil is 14.0% in only 35 days with viability nearly 0, as compared with only a 2% increase in FFA in 55 days at 65% R.H. and with smaller loss in viability (Table I and II).

Mechanical damage hastens seed deterioration; wetting of damaged seed enormously increases the rate and degree of deterioration (Table III B). Ammonia and acetic acid treatments of the seed, reported in the literature to be beneficial, do not appear to be of much use at any rate when the seed is stored at lower humidities (Table III A).

TABLE III

Storage of Variously-Treated Seed in Air-tight Tins Under Laboratory Atmospheric Conditions

A. Pre-dried seed and chemically-treated seed.

Days	Blank (untreated)		Pre-dried		Ammonia-treated		Acetic acid-treated	
	M%	F%	M%	F%	M%	F%	M%	F%
0	8.3	1.3	3.9	1.3	7.0	1.6	7.0	1.6
17	6.9	1.5	4.4	1.4	...	...	...	...
27	...	...	...	...	8.3	1.6	8.0	1.7
61	7.7	1.7	4.3	1.5	8.2	1.7	7.9	1.8
92	8.6	1.9	...	1.7	...	...	...	...
207	10.2	2.7	6.2	2.0	11.2	2.5	10.9	2.7

B. Damaged, and damaged and wetted seed.

Days	Blank (untreated)		20% damaged		10% damaged		5% damaged		10% damaged and wetted	
	M%	F%	M%	F%	M%	F%	M%	F%	M%	F%
0	8.3	1.3	8.9	1.3	8.9	1.3	8.3	1.3	7.0	1.6
17	6.9	1.5	8.0	1.6	7.6	1.6	7.3	1.5	...	...
27	...	...	...	...	...	...	...	...	18.3	10.6 (turned mouldy)
61	7.7	1.7	9.3	6.5	9.0	5.3	8.6	3.1	17.3	32.8
92	8.6	1.9	9.4	8.7	9.1	6.7	8.9	4.8	...	...
207	10.2	2.7	11.5	14.5	11.5	9.0	10.7	5.9	16.1	39.7

(M=Moisture in seed. F=Free fatty acids in seed oil.)

Delinted seeds appear to attain moisture equilibrium more rapidly and to develop FFA slightly faster, due either to the absence of protective linters or to slight mechanical damage during delinting.

Storage of seed in loose pyramidal heaps causes slightly less deterioration than storage in stacked bags, perhaps because of better aeration in the former (Tables IV and V).

TABLE IV

Storage in Gunny Bags of American Parbhani Seed

Months of seed storage	0 (March)	5 (August)	8 (November)	13 (April)	17 (August)
Moisture in seed (%)	...	9.2	8.2	7.0	10.9
FFA in seed oil (%)	1.2	2.7	3.2	3.5	3.8
Refining loss (%)	7.3	9.1	12.9	13.4	13.9
Refined oil colour (as Y+10R units in 1—inch cell)	61	50	67	98	107
Bleached oil colour (as Y+10R units in 1—inch cell)	6.6	15	25	38	45

TABLE V

Storage in Heaps of American Parbhani and Gaorani–6 Seed

Months of seed storage	American Parbhani			Gaorani–6		
	0 (February)	2 (April)	6 (August)	0 (February)	2 (April)	6 (August)
Moisture in seed (%)	8.3	5.4	10.4	7.6	6.0	11.1
FFA in seed oil (%)	1.4	2.	2.7	1.4	2.0	2.9
Crude oil colour (4 vols. hexane, 0.25—inch cell)	16.0Y 3.5R	12.0Y 4.2R	17.0Y 5.6R	22.0Y 6.4R	25.0Y 6.5R	25.0Y 7.3R
Refining loss (%)	8.0	9.2	10.5	6.9	8.9	10.9
Refined oil colour (as Y+10R units, 1—inch cell) ...	67	79	91	88	91	98
Bleached oil colour (as Y+10R units, 1—inch cell) ...	9.5	13	20	13.6	16	27

Storage and Stability of Cottonseed Oil

Once expressed, cottonseed oil, like all other fats, is also subject to deterioration; the pigments in the oil are particularly prone to degradation. The content of natural pigments in seed is important, but the actual release of pigment into oil is the result of several factors. High moisture in seed *e.g.*, during cooking or during seed storage, causes the release of pigment into the crude oil. Oils rich in gossypol are more liable on storage to colour fixation by pigment oxidation. Thus crude oil storage results in changes similar to those occurring in stored seed. However, owing to the outstanding stability conferred by the natural antioxidants gossypol and tocopherol, FFA development is less prominent in the crude oil, but there is a definite fixation of colour during storage as evidenced by darker bleached oils (Table VI). Refined or bleached oils can be stored with negligible changes in colour or FFA (Table VII).

TABLE VI

Storage of Crude Cottonseed Oil in Tins

Days of storage	0	20	40	55	70
FFA (% oleic)	5.0	5.1	5.2	5.2	5.4
Refining loss (%)	16.5	16.5	17.0	16.8	15.5
Refined oil colour 0.25—inch cell	8.0Y 0.8R	8.0Y 0.9R	8.0Y 1.0R	9.0Y 1.1R	10.0Y 1.4R
Refined oil colour as Y+10R units	16	17	18	20	24
Bleached oil colour 0.25—inch cell	1.7Y 0.2R	1.8Y 0.3R	2.0Y 0.4R	2.0Y 0.5R	3.3Y 0.6R
Bleached oil colour as Y+10R units	3.7	4.8	6.0	7.0	9.3
Bleaching colour reduction (%)	76.9	71.9	66.7	65.0	61.3

TABLE VII

Storage of Refined Cottonseed Oil in Tins

A. Laboratory-refined oil.

Days of storage	0	25	40	60
FFA (% oleic)	0.05	0.03	0.03	0.11
Refined oil colour as Y+10R units (0.25—inch cell) ...	16	16	16	16
Bleached oil colour as Y+10R units (0.25—inch cell) ...	3.7	3.6	4.7	5.0

B. Factory-refined oil.

Days of storage	0	2	50
FFA (% oleic)	0.03	0.04	0.04
Refined oil colour as Y+10R units (0.25—inch cell)	19	17	17
Bleached oil colour as Y+10R units (0.25—inch cell)	1.7	1.8	1.5

Crude cottonseed oil is extremely stable and there is little change either in FFA or peroxide value; the latter increases by only 1-2 units after 130 days of shelf storage. Refined oil on the other hand shows an increase in peroxide value by about 180 units for the same period, but in neither of the oils could any organoleptic rancidity be detected. Antioxidants do not appear to confer any protection under shelf storage conditions. Accelerated stability tests indicate that catechin, NDGA and BHA offer slight protection to crude, and moderate protection to refined, cottonseed oil. At 0.05% levels of these antioxidants, the peroxide values were 35.9, 41.6, 41.2 respectively after 52 hours against a value of 45.0 for the blank crude oil. Refined oil shows a peroxide value in 7-8 hours of 33.6 (with 0.05% catechin), 22.9 (with 0.1% catechin) and 23.5 (with 0.05% BHA) as against 57.6 for the blank oil.

Recommendations for Cottonseed and Oil Storage

With the above results and the background of Indian conditions of harvesting, ginning, storage and transport, certain suggestions are put forward for better storage of the seed and the oil which would result in a quality of cottonseed oil superior to that obtained at present.

1. Of the various factors contributing to subsequent deterioration, damage by water is the most vicious and must be prevented at every stage after harvesting. Cheap polyethylene sheets could advantageously be used to prevent wetting of seed during storage or transport. Mechanical damage during ginning, or during loading and stacking by throwing bagged seed from great heights, should be avoided.

2. It is desirable to institute seed grading on the basis of simple but important tests like moisture content and FFA of representative samples. Even better would be to expel a small quantity of seed and examine the refinability and bleachability of the oil obtained.

3. Pre-drying of moist seed by hot air blowers, or simply though less effectively by sun drying, greatly helps to increase storage life of the seed. The practice in U.S.A. of storing the seed according to the initial FFA and of expelling the stored lots in order of decreasing acidity can be usefully followed in this country.

4. If the seed has to be stored, it is best done in covered and floored sheds, preferably walled all round and frequently fumigated.

5. The present study has clearly shown that pronounced fixation of colour occurs in stored seed as also in the crude oil. It is desirable however to store crude oil in preference to the seed since the development of free acids is very much less in the oil, though pigment fixation is greater. Proper seed storage is an elaborate affair while oil storage is much simpler and more economical. It is best to store refined or refined and bleached oils; here the absence of a major part of the pigments which have been removed during refining results in negligible FFA increase and practically no colour fixation. Incorporation of well-known antioxidants like catechin, BHA or NDGA will help to retard any oxidative rancidity.

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5. STORAGE STUDIES OF COTTONSEED OIL–PART I.

Effect of Filterpressing on the Keeping Qualities, and of Storage on Refining Characteristics, of Crude Cottonseed Oil

By

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The effect of filterpressing of expeller crude cottonseed oil on its keeping qualities on storage in tins for 6 months at laboratory temperature was studied for two different oils. Filterpressed oils were found to keep better than unfiltered oils but no difference in the Lovibond colours were noticed.

Studies have also been carried out on the storage of three different crude cottonseed oils at room temperature, with respect to their refining characteristics. It was found that on storage, while no significant difference in the refining losses were observed, the removal of colour became increasingly difficult with the length of storage, apparently due to colour fixation. Hence, refining of the crude oil soon after its production is desirable.

Introduction

Cottonseed oil, which is an edible oil, presents many problems in the milling, refining and hydrogenation industries. One is the storage of oil either in the crude or refined state, important for the following reasons:

(i) Cottonseed oil contains gossypol and gossypol-like pigments which undergo a number of changes like decomposition and oxidation, with the result that the colour properties of cottonseed oil vary very widely from oil to oil and in the same oil from time to time. The increase in refined and bleach colours during storage of crude cottonseed oil, known as colour reversion or colour fixation, is one of the major problems in the way of utilizing cottonseed oil for food industries.

(ii) While the crushing of cottonseed is readily adopted by Indian mills, though not on the proper lines in many cases, this is not so in regard to refining, due to paucity of equipment and information on the processing methods. Due to this and a number of other factors, there exist long periods between production of crude cottonseed oil and its subsequent processing and during this intervening period, the crude oil is liable to undergo some deteriorative changes.

(iii) The pigment systems in the three broad varieties of cottonseed produced in India, namely, indigenous *desi*, improved *desi* and American, are likely to be different and hence on storage of the crude oils obtained from these seeds are also likely to undergo changes of different kinds and to different extents. Further, in several parts of India, the American-type seed as it comes into the markets is found admixed with the *desi*-type seed to the extent of 10-20%. The oil produced from such seed is likely to contain non-uniform pigment systems difficult to deal with in refining and bleaching.

(iv) Indian cottonseed is found to contain a fair amount of "bollie" seed, *i.e.*, seed from bolls which are prematurely opened due to several factors in the growth of the plant. Therefore, the crude cottonseed oil produced in India inevitably contains some oil from "bollie" seed. It is reported[1] that "bollie" seed oil rapidly darkens on storage and further that mixing "bollie" oil with normal oil causes rapid deterioration in the colour of the latter.

The storage problem of cottonseed oil has attracted much attention. From small-sample storage and industrial storage studies, King[2] concluded that if cottonseed oil is to be stored industrially, it is preferable to do so in the refined state rather than as crude, and the advantages of storing cottonseed oil as crude from a stability point of view as shown by the results of the small-sample storage tests are contradicted by the results of the large industrial storage tests. He also concluded that good quality crude cottonseed oil can be stored without any prohibitive deterioration in quality characteristics for 5 months at least in cool weather. Williams *et al.*[3] in their storage studies on colour development in cottonseed oil (hydraulic and screw-pressed) correlated the rate of increase of bleach colours in the oils during storage of seed and crude oils with temperature of storage and changes in the absorption spectra of the oils. Narayana Rao[4] used peroxide values to study the stability of crude, refined and bleached cottonseed oil from the standpoint of the effect of the material of the containers, by storing in glass, aluminium and tinned brass containers for a period of three months. Harwalkar and Saletore[5] studied the storage of crude and refined cottonseed oils and their stability during shelf storage and under accelerated conditions.

The present studies are confined to two aspects, *viz.*, (i) the effect of the presence of foots in the expeller cottonseed oil on its storage behaviour under laboratory conditions, and (ii) the effect of ageing crude cottonseed oil on its subsequent refinability.

Experimental

To study the first aspect, 10 lbs. each of unfilterpressed and filterpressed crude cottonseed oils from two different pilot-plant runs made at this Institute were stored in tins soon after their production. These oils were stored at laboratory room temperature in closed tins for a period of 180 days. Samples were drawn at fortnightly intervals and analysed for free fatty acids, peroxide values and Lovibond colours. The results are presented in Tables I and II.

The second aspect of the refining characteristics of crude cottonseed oil on storage was studied by taking 30 lbs. of freshly-expelled and filterpressed crude oil from each of three different pilot-plant runs and storing in tins under identical laboratory conditions for 180 days. Samples were drawn fortnightly and refined and bleached according to A.O.C.S. Methods. Lovibond colours of crude, refined and bleached oils were also determined. The results are given in Tables III to V.

TABLE I

Analytical Data for Unfilterpressed and Filterpressed Cottonseed Oil During Storage

SAMPLE 1

(Date of commencement of storage: 21-5-56; Date of completion: 21-11-56)

Storage period in days	Unfilterpressed oil			Filterpressed oil		
	F.F.A. Per cent	Peroxide value	Lovibond colour in 0.25-inch cell Y R	F.F.A. Per cent	Peroxide value	Lovibond colour in 0.25-inch cell Y R
0	2.96	0.00	91 10 (191)	2.97	0.00	91 10 (191)
15	3.42	0.40	91 11 (201)	3.15	0.12	91 10 (191)
30	3.63	0.40	91 11 (201)	3.22	0.30	91 10 (191)
45	3.84	1.10	91 12 (211)	3.46	0.78	91 11 (201)
60	3.90	1.80	91 12 (211)	3.42	1.26	91 11 (201)
76	3.84	1.76	92 12 (212)	3.27	1.40	92 12 (212)
91	3.85	1.15	92 11 (202)	3.28	1.12	92 11 (202)
107	3.83	0.97	92 11 (202)	3.36	0.97	92 11 (202)
122	3.89	1.32	92 11 (202)	3.41	1.07	92 11 (202)
137	3.93	1.48	92 11 (202)	3.41	1.21	92 11 (202)
153	3.94	1.63	92 11 (202)	3.48	1.33	92 11 (202)
168	3.91	1.65	92 11 (202)	3.54	1.40	92 11 (202)
183	3.98	1.75	92 11 (202)	3.59	1.44	92 11 (202)

1. Figures in brackets represent colour readings expressed as (Y+10R) units.
2. Peroxide value is expressed as millimoles of peroxides per kg. of fat.

TABLE II

Analytical Data for Unfilterpressed and Filterpressed Cottonseed Oil During Storage

SAMPLE 2

(Date of commencement of storage: 5-9-56; Date of completion: 6-3-57)

Storage period in days	Unfilterpressed oil			Filterpressed oil		
	F.F.A. Per cent	Peroxide value	Lovibond colour in 0.25-inch cell Y R	F.F.A. Per cent	Peroxide value	Lovibond colour in 0.25-inch cell Y R
0	2.60	0.00	96 8 (176)	2.56	0.00	96 8 (176)
16	2.55	0.00	96 8 (176)	2.53	0.00	96 8 (176)
31	2.55	0.00	96 8 (176)	2.51	0.00	96 8 (176)
47	2.62	0.175	96 9 (186)	2.54	0.15	96 8 (176)
62	2.61	0.30	96 8 (176)	2.55	0.30	96 9 (186)
77	2.63	0.49	96 8 (176)	2.55	0.50	96 9 (186)
92	2.64	0.50	96 10 (196)	2.55	0.37	96 9 (186)
114	2.72	0.40	96 10 (196)	2.62	0.40	96 9 (186)
124	2.72	0.42	96 10 (196)	2.64	0.40	96 9 (186)
139	2.77	0.98	96 10 (196)	2.65	0.94	96 9 (186)
154	2.79	1.28	96 10 (196)	2.70	1.09	96 9 (186)
169	2.79	1.23	96 11 (206)	2.73	1.08	96 10 (206)
182	2.84	1.30	96 10 (196)	2.76	1.10	96 9 (186)

1. Figures in brackets represent colour readings expressed as (Y+10R) units.
2. Peroxide value is expressed as millimoles of peroxide per kg. of fat.

TABLE III

Refining Characteristics of Crude Cottonseed Oil on Storage

SAMPLE 1

Produced from Gaorani-6 variety on 16-5-1956.

(Date of commencement of storage: 26-5-56; Date of completion: 22-11-56)

Storage period in days	F.F.A. of crude oil per cent	Refining loss per cent	Lovibond colour in 0.25-inch cell						Colour fixation expressed as per cent increase on the initial colour	
			Crude oil		Refined oil		Bleached oil		Refined colour	Bleach colour
			Y	R	Y	R	Y	R		
0	2.98	16.3	91	10	9.5	1.1	2.4	0.3	0	0
			(191)		(20.5)		(5.4)			
14	3.13	16.0	91	11	9.6	1.1	2.4	0.3	0.5	0
			(201)		(20.6)		(5.4)			
33	3.14	16.5	91	11	9.6	1.2	2.8	0.3	5.4	7.4
			(201)		(21.6)		(5.8)			
46	3.15	16.2	91	12	9.6	1.1	2.8	0.3	0.5	7.4
			(211)		(20.6)		(5.8)			
61	3.17	16.6	91	12	9.5	1.1	3.6	0.4	0	40.7
			(211)		(20.5)		(7.5)			
76	3.21	16.1	91	12	9.6	1.2	3.6	0.4	5.4	40.7
			(211)		(21.6)		(7.6)			
91	3.23	16.1	91	12	9.7	1.2	3.8	0.4	5.9	44.4
			(211)		(21.7)		(7.8)			
107	3.36	15.9	92	11	9.8	1.3	4.2	0.5	11.2	70.4
			(202)		(22.8)		(9.2)			
122	3.51	16.3	92	11	9.9	1.3	4.4	0.5	11.7	74.1
			(202)		(22.9)		(9.4)			
136	3.53	16.2	92	12	10.0	1.5	4.6	0.5	22.0	77.7
			(212)		(25.0)		(9.6)			
151	3.54	16.0	92	12	10.2	1.7	6.6	0.6	32.7	133.3
			(212)		(27.2)		(12.6)			
166	3.57	16.2	92	12	10.4	1.7	8.0	0.8	33.7	196.3
			(212)		(27.4)		(16.0)			
182	3.59	16.2	92	12	10.5	1.7	8.0	0.8	34.1	196.3
			(212)		(27.5)		(16.0)			

1. Figures in brackets represent colour readings expressed as (Y+10R) units.

TABLE IV

Refining Characteristics of Crude Cottonseed Oil on Storage

SAMPLE 2

Produced from Gaorani-12 variety on 3-7-56.

(Date of commencement of storage: 18-7-56; Date of completion: 17-1-57)

Storage period in days	F.F.A. of crude oil per cent	Refining loss per cent	Lovibond colour in 0.25-inch cell			Colour fixation expressed as percentage increase on the initial colour	
			Crude oil Y R	Refined oil Y R	Bleached oil Y R	Refined colour	Bleach colour
0	5.09	23.4*	75 12 (195)	9.8 0.9 (18.8)	2.1 0.2 (4.1)	0	0
15	5.16	24.0*	75 12 (195)	9.8 0.9 (18.8)	2.1 0.2 (4.1)	0	0
30	5.20	22.1	75 12 (195)	9.8 0.9 (18.8)	2.4 0.2 (4.4)	0	7.3
47	5.25	22.0	75 12 (195)	9.8 0.9 (18.8)	2.6 0.2 (4.6)	0	12.2
62	5.25	22.3	75 12 (195)	9.8 0.9 (18.8)	2.7 0.3 (5.7)	0	39.0
78	5.33	21.6	75 12 (195)	9.9 1.0 (19.9)	2.8 0.3 (5.8)	5.9	41.5
93	5.33	21.2	75 12 (195)	9.9 1.0 (19.9)	2.9 0.3 (5.9)	5.9	43.9
110	5.40	22.6	75 12 (195)	10.0 1.0 (20.0)	2.9 0.3 (5.9)	6.4	43.9
123	5.40	21.0	75 12 (195)	10.0 1.0 (20.0)	3.0 0.3 (6.0)	6.4	46.3
138	5.45	21.3	75 12 (195)	10.0 1.0 (20.0)	3.1 0.3 (6.1)	6.4	48.8
153	5.27	21.6	75 12 (195)	10.1 1.0 (20.1)	3.1 0.3 (6.1)	6.9	48.8
168	5.47	20.9	75 12 (195)	10.2 1.1 (21.2)	3.3 0.4 (7.3)	12.8	78.0
183	5.51	21.0	75 12 (195)	10.1 1.2 (22.3)	3.3 0.4 (7.3)	18.6	78.0

1. Figures in brackets represent colour readings expressed as (Y+10R) units.
2. * In the first two cases, firm foots were not obtained and hence the higher refining losses recorded.

TABLE V

Refining Characteristics of Crude Cottonseed Oil on Storage

SAMPLE 3

Produced from Lakshmi variety on 4-9-1956.

(Date of commencement of storage: 25-9-56; Date of completion: 22-3-57)

Storage period in days	F.F.A. of crude oil per cent	Refining loss per cent	Lovibond colour in 0.25-inch cell						Colour fixation expressed in per cent increase on the initial colour	
			Crude oil		Refined oil		Bleached oil		Refined colour	Bleach colour
			Y	R	Y	R	Y	R		
0	2.53	10.9	96 (176)	8	8.8 (13.8)	0.5	1.4 (2.4)	0.1	0	0
14	2.55	11.0	96 (176)	8	8.7 (13.7)	0.5	1.4 (2.4)	0.1	0	0
29	2.58	10.3	96 (176)	8	8.7 (13.7)	0.5	1.4 (2.4)	0.1	0	0
44	2.58	10.4	96 (176)	8	8.7 (13.7)	0.5	1.5 (2.5)	0.1	0	4.2
59	2.58	10.5	96 (176)	8	8.8 (13.8)	0.5	1.5 (2.5)	0.1	0	4.2
74	2.62	10.9	96 (176)	8	8.8 (13.8)	0.5	1.7 (2.7)	0.1	0	12.5
88	2.66	10.9	96 (176)	8	8.9 (14.9)	0.6	1.8 (2.8)	0.1	8.0	16.7
104	2.66	11.0	96 (176)	8	9.1 (15.1)	0.6	1.9 (3.9)	0.2	9.4	62.5
119	2.68	11.0	96 (176)	8	9.4 (15.4)	0.6	2.5 (4.5)	0.2	11.6	87.5
134	2.68	11.1	96 (176)	8	9.8 (16.8)	0.7	2.6 (4.6)	0.2	21.7	91.7
149	2.68	11.0	97 (177)	8	10.1 (17.1)	0.7	2.7 (5.7)	0.3	23.9	137.5
163	2.69	11.4	97 (177)	8	10.1 (17.1)	0.7	2.7 (5.7)	0.3	23.9	137.5
178	2.70	11.6	97 (177)	8	10.3 (18.3)	0.8	2.7 (6.7)	0.4	32.6	179.2

1. Figures in brackets represent colour readings expressed as (Y+10R) units.

Discussion

From the data given in Tables I and II, it is seen that there is slightly greater increase in the F.F.A. of unfilterpressed oils (2.96 to 3.98 and 2.60 to 2.84) than those of the corresponding filterpressed oils (2.97 to 3.59 and 2.56 to 2.76) respectively during the storage period of 180 days. A similar tendency is noticed in the case of peroxide values also of the two types of oils, the peroxide values of unfilterpressed oils being higher in both cases than those of the corresponding values for filterpressed oils. The peroxide values of filterpressed oils have slightly lagged behind those of unfilterpressed oils throughout the storage period. From this, it is concluded that these filterpressed oils are somewhat more stable on storage than the corresponding unfiltered oils. This observation is the opposite of the result reported by us earlier[6] for the storage of unfilterpressed and filterpressed groundnut oils, where it was found that the unfilterpressed oils were found to be somewhat more stable than the filterpressed oils. Incidentally, the increase in the peroxide values of the two samples of crude cottonseed oils on storage for 180 days studied in the present work are from nil to 1.75, 1.30, 1.44 and 1.10 respectively for the two unfiltered and filtered oils. In the case of two samples of crude groundnut oils the peroxide values rose from 3.60 to 58.1 and 3.0 to 59.8 for the unfiltered oils and 2.0 to 63.0 and 3.1 to 61.4 for the filterpressed oils respectively on storage for the same period. From these peroxide values, it can be seen that the stability of crude cottonseed oils is incomparably greater than that of the crude groundnut oils.

The data given in Tables III, IV and V show that the actual rise in F.F.A., of the three samples during the storage period of 6 months is respectively 0.61%, 0.4% and 0.2%. There should have been some corresponding increase in the refining loss with the storage of these samples. But the results obtained on the refining loss of all the three samples are practically constant, with slight fluctuations in an erratic manner. It has yet to be seen how the trend of refining loss would be on industrial or bulk storage. The Lovibond colours of these three crude oils during the storage period of 6 months has remained practically constant. But the corresponding refined and bleach colours of the stored crude oils exhibit some interesting features. While the increase in the refined colours of the three crude oils at the end of the storage period of 6 months is respectively 34.1, 18.6 and 32.6% over their initial colours, the corresponding increase in their bleach colours are 196.3%, 78.0% and 179.2% respectively, showing that the increase of the bleach colours is about 4 to 6 times those of the corresponding refined colours. Thus, while the colour fixation is apparently imperceptible in crude oil, it is marked in the corresponding refined oils and remarkably high in the corresponding bleached oils.

We consider that this behaviour of crude cottonseed oil on storage is of significance in the standardisation of quality of cottonseed oil. As previously observed by Achaya *et al.*[7] the present Indian Standard Specification for "Washed Cottonseed Oil" only specifies the raw oil colour and colour-fixed oils may well pass the test. Therefore, they consider it necessary to include a clause regarding the minimum bleach colour to be obtained from such "washed oils." They based their recommendations on the increased refined and bleach colours of crude oils obtained from the seed stored. The data presented in this paper on the bleach colours of stored crude oils also points out the importance of including the bleach colour of the "washed oils" in the specifications for the latter.

From Tables III, IV and V, it is seen that the refined colours of the three crude oils have not significantly changed even at the end of 76, 62 and 74 days and the bleach colours have not changed significantly even at the end of 46, 47 and 59 days of storage in samples 1, 2 and 3 respectively. These results indicate the desirability of refining and bleaching crude cottonseed oils within two months of their production to prevent the risk of colour fixation to any significant extent. However, it is considered necessary to make similar detailed studies on a large number of crude oils produced from various varieties of seed.

Summary and Conclusions

(1) Storage studies for six months at room temperature have been made on the effect of filterpressing of two expeller oils and the data presented. The results show that the filterpressed oils keep better than the unfilterpressed oils both in respect of acidity and peroxide development. No change was noticed in the two oils with regard to Lovibond colour during the storage period.

(2) Storage studies were also made with regard to refining characteristics on three different samples of crude cottonseed oils at room temperature for a period of six months, and the data presented.

(3) It was found that while there is no material change in the F.F.A. of the three oils and in their corresponding refining losses during storage, colour fixation definitely took place in the three oils during storage, and colour removal became increasingly difficult with the length of storage of the crude oils. The extent of colour fixation in the crude oils in the present study indicated that crude cottonseed oils should be refined and bleached within 2 months of their production in order to prevent any significant fixation of colour.

(4) It is recommended that the bleach colour of "washed oils" should also be included in the I.S. specification for the latter oils.

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6. STUDIES ON THE STABILITY OF WINTERIZED COTTONSEED OIL

By

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The physical and chemical constants of winterized cottonseed oil as well as those of the original refined and bleached oil have been determined. The autoxidative stability of cottonseed oil is not materially affected on winterization. Propyl and dodecyl gallates along with citric acid as a synergist are effective in retarding the development of peroxides.

Introduction

In the preparation of some foods, the consistency of the oil is a matter of great importance. For example, a liquid oil which does not solidify at 0-4°C should be used in preparing green salads. In the U.S.A. considerable quantities of salad oil prepared from winterized cottonseed oil are being utilized for the manufacture of mayonnaise and salad dressings.[1] The composition and keeping quality of the winterized oil will depend on the conditions of winterization. Apart from the recent work of Mack, Moore and Bickford[2] on the chemical composition and the autoxidative stability of three samples of winterized cottonseed oil by the active oxygen method, no information is available regarding the keeping quality of winterized cottonseed oil. The present paper deals with studies on the keeping quality of winterized cottonseed oil stored in glass and tin containers with and without the addition of some antioxidants and synergists.

Experimental

Preparation of Winterized Cottonseed Oil. A sample of crude cottonseed oil was refined and given a light bleach according to the procedure described by Narayana Rao and Kuppuswamy.[3] The bleached oil was kept in a cold chamber maintained at 40-43°F for a period of 5 days, during which the solid stearine fraction separated out. The winterized oil was decanted and then filtered at the same temperature. The yield of the winterized oil was 76 per cent of the refined and bleached oil.

Characteristics of the Oil. The various physical and chemical constants and the cold test of the winterized oil as well as that of the original refined cottonseed oil were determined according to the standard methods of the American Oil Chemists' Society.[4] Total tocopherol content of both winterized and unwinterized cottonseed oil was estimated according to the Emmerie and Engel method as modified by Parker and McFarlane.[5] Results of these determinations are presented in Table I.

Keeping Quality of the Oil. Samples of winterized cottonseed oil and refined and bleached cottonseed oil were stored in the dark in glass bottles and tin cans both at room temperature (23-30°C) and at 37°C. In order to study the effect of certain antioxidants and synergists on the keeping quality of the oils, dodecyl gallate and propyl gallate (at 0.02 per cent

TABLE I

Characteristics of Refined and Bleached, and of Winterized Cottonseed Oil

Constituents	Refined & Bleached oil		Winterized oil	
	Present investigation	Literature values [1,2]	Present investigation	Literature values [1,2]
Colour*	12.5Y 1.1R	35–70Y 3.2–6.1R	12.0Y 1.0R	35–70Y 3.2–4.1R
Iodine value	105.3	102–114	109.2	103–116.8
Thiocyanogen value	65.8	64–69	68.1	67–71
Linolein%	48.8	47–51	50.8	49–56
Olein%	24.2	19–21	25.0	22–25
Saturated glycerides%	27.0	23–27	24.2	19–29
Total tocopherols%	75 mg.	60–120 mg.	87 mg.	75–150 mg.
Cold test	...	...	8 hrs.	...

* (Lovibond Units, 1–cm. cell)

TABLE II

Effect of Antioxidants and Synergist on the Development of Peroxides* in Cottonseed Oil

Period of storage (days)	Refined and bleached oil						Winterized oil					
	Control		Dodecyl gallate+citric acid		Propyl gallate+citric acid		Control		Dodecyl gallate+citric acid		Propyl gallate+citric acid	
	Glass	Tin	Glass	Tin	Glass	Tin	Glass	Tin	Glass	Tin	Glass	Tin
	Storage Temperature 23-30°C											
0	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
15	14.0	15.0	7.5	7.5	7.5	8.0	14.5	15.5	7.5	8.0	7.5	8.5
30	23.0	25.0	8.0	8.5	8.5	8.5	22.5	25.5	8.5	9.0	8.5	9.0
45	33.0	36.5	8.5	10.0	9.0	9.5	34.0	38.0	8.5	11.0	9.5	9.5
60	45.0	50.5	9.5	11.5	10.0	11.0	46.0	53.0	9.5	12.5	10.0	12.0
75	60.0	57.5	10.0	13.0	10.5	12.0	62.5	69.5	10.5	14.0	11.0	13.5
90	80.0	89.5	11.0	15.0	11.0	14.0	83.5	93.5	11.5	16.0	12.5	15.0
	Storoge Temperature 37°C											
0	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
15	20.0	22.0	8.5	9.0	8.0	8.5	21.5	23.0	8.5	9.5	8.0	8.5
30	41.0	44.5	11.0	11.0	10.5	11.0	42·5	46.0	11.5	11.5	10.5	11.0
45	70.5	79.5	12.0	13.5	11.0	13.5	73.0	80.0	12.5	14.5	11.5	14.0
60	109.0	124.0	14.5	16.5	12.5	15.0	112.5	126.0	15.5	17.0	13.5	16.0
75	148.5	163.5	16.0	19.0	14.0	17.0	152.0	166.5	17.0	20.5	15.5	18.5
90	195.0	209.5	18.0	22.0	16.0	19.5	200.0	214.5	19.0	23.5	17.5	21.5

* Expressed as ml. of 1 N Sodium thiosulphate per kg. of fat.

level) and synergist citric acid (at 0.01 per cent level) were added. The samples containing the antioxidants and synergist were stored under the same conditions as the control samples. The peroxide values of different samples were determined at intervals of 15 days during a period of three months according to the procedure of Wheeler.[6] The results are given in Table II.

Results and Discussion

Table I shows that winterization did not appreciably affect the colour of refined cottonseed oil. A slight increase in the iodine value, the glycerides of oleic and linoleic acids and the tocopherol content, and a decrease in the saturated glycerides, were noted in the winterized oil.

The data in Table II show that the keeping quality of the winterized oil is nearly of the same order as that of the unwinterized cottonseed oil in spite of the slightly higher iodine value of the former. Similar observations have been made by Mack *et al.*[2] Both the oils developed peroxides more rapidly at 37°C than at room temperature (23-30°C). Oils stored in tin cans developed slightly higher peroxide values than those stored in glass bottles. The development of higher peroxide values in vegetable oils when stored in tin containers as compared to glass has been observed by other workers[7,8]. The two esters of gallic acid (propyl gallate and dodecyl gallate) in the presence of citric acid were found effective in retarding oxidative rancidity in unwinterized and winterized cottonseed oil stored in glass and tin containers.

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7. SOME ASPECTS OF THE CULTIVATION & STORAGE OF COTTONSEED AND OF THE REFINING OF CRUDE COTTONSEED OIL

By

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The paper reviews methods for improving the yield of cottonseed and precautions to be taken in the storage of the seed to obtain oils of good quality.

The question of gossypol colour-stabilisation and its prevention are discussed along with the refining and bleaching of crude cottonseed oil.

Introduction

Archaeological evidence indicates that as early as 3000 B.C. cotton was used in India for making fabrics. Also the crushing of cottonseed to obtain the oil dates back to the early Hindu writings. Old medical books have recommended cottonseed oil for external applications. Centuries have since passed but little progress seems to have been made in the technological fields of this industry in India. Cotton cultivation is carried out for the fibre value; the intrinsic value of the seed and other by-products is being cashed in in most other countries but not in India. For example, in 1955-56 the total production of cottonseed in India was 1.4 million tons, out of which the seed utilized for crushing was only 65,615 tons. An attempt is here made to elucidate the general causes responsible for the poor quality of cottonseed oil, and methods used to overcome them.

In all cases where the cottonseed oil manufactured is of a poor quality, the underlying cause is the damage to the seeds, which may occur in the following ways: (1) Field damage, (2) storage damage, and (3) damage at the processing stage. These points are discussed individually below:

Field Damage

Field damage is the result of humid weather during the opening of the bolls, limited supply of soil moisture, insufficient fertilizer supply and excessive rainfall. According to Gallup[1] the gossypol and oil contents of cottonseed are determined principally by the locality in which the plants are grown and are influenced slightly by an additional supply of plant nutrients. For example, in the U.S.A. seeds from the South-West are of low oil and gossypol contents and seeds from the Pacific Coast region are highest in gossypol. Field damage may also result from heavy frost which causes premature opening of the bolls, resulting in immature or bollie seeds. Similarly, plants infected by leaf worms or which have undergone a period of drought also yield bollie seeds. Such seeds yield oil which exhibit colour reversion. The colour reversion usually observed in refined and bleached oils may be due to expression of the oils from immature seeds.

There is also the colour reversion usually observed in refined and bleached cottonseed oil, but this is due to the limited oxidation of γ-tocopherol to chroman 5,6-quinone; but these again bleach to a light colour on continued oxidation.[2]

(a) *Prevention of Field Damage.* The foliage which acts as a blanket to retain the moisture within the boll should be cut off. This helps the crop to have better access to sunlight and facilitates reduction of the moisture in the seeds. Since excess moisture is the main cause for initiating the deterioration, this method helps to minimise seed deterioration at the cultivation stage.

(b) The crop should not be left in the field during rainy or humid season in the hope that atmospheric conditions will become favourable. The best way is to pick raw cotton even in the wet condition as soon as the bolls open, then dry the seed before ginning.

(c) *Hormone Sprays.* In those areas where field damage is extensive, it may be advantageous to investigate the feasibility of employing plant hormone treatment to accelerate maturation so that the bolls can be made to open sooner and thus dry under more favourable conditions, eliminating field damage to the seeds. Such treatment has been carried out in our country for the groundnut crop and may well be extended to cottonseed also.

(d) *Regulating Fertilizer Supply.* An increased percentage of nitrogen in the fertilizer helps to increase the number of seeds per boll over the normal figure of 40 seeds. Thus, this method helps to increase yield of seeds per acre under cultivation. Also, it has been observed that an increased percentage of nitrogen reduces the gossypol content of the seed. Since gossypol is the main mischief-maker in the cottonseed industry, a means of minimising the gossypol in seed would be welcome.

Field-damaged seeds have a greenish background, or in the case of extensive damage, a greenish-brown colour. To discriminate between bollie seeds and prime mature seeds, Chester[3] has proposed a method whereby the seeds are delinted with acids, after which they are covered with water. The seeds which float are rejected. It was found that nearly all internally-infected and weak seeds could be removed by this means.

Storage Damage

In addition to damage suffered at the time of cultivation, the seeds undergo further damage during their storage prior to processing, particularly seeds of high moisture content.

(a) *Mechanism of Seed Deterioration.* The biological processes which take place in stored wet seed liberate heat. Due to the insulating effect of the lint on the seed, the heat generated is not readily dissipated, and the mass of seed rises in temperature. High-moisture seeds are wet enough to permit considerable enzyme activity with accompanying gradual digestive breakdown of the oil, carbohydrates and protein in the kernel.

The oil in moist seeds also undergoes lipolysis into free fatty acids. High moisture content and high temperature during storage accelerate lipolysis. Immature or bollie seeds are highly susceptible to lipolysis.

It seems probable that certain transformations occurring in moist seed during storage can be attributed to the action of water on the gland. Most of the pigments of the seed are concentrated in the glands. Gossypol is present to the extent of 21-39% of the weight of the pigments. During the storage of moist seed the water-sensitive gland wall furnishes inadequate protection to the polyphenolic intra-glandular pigments from the oxidising action of the reactive components of the seed tissue. These pigments are then believed to be partially converted to the more deeply-coloured quinoid compounds. Hence, deteriorated seeds have high F.F.A. and yield poor-quality oil.

The gossypol in such deteriorated seeds is inactivated and exists as "bound gossypol." Similarly, when seeds are cooked before expression for oil, the gossypol is inactivated to "bound gossypol." Both cases of inactivation are attributed to the combination of the gossypol with the cottonseed protein to give quinoid compounds, which are deep red in colour and may cause the intense red colour of the expressed cottonseed oil. The greater the conversion of the gossypol to "bound gossypol" the more intense will be the colour of the oil.

Microscopic examination of the seed sections reveals that the presence of moisture determines the rate at which the pigment glands are ruptured and their contents expelled into the surrounding tissue. In moistened seed, some of the pigment glands were ruptured even without heating. The glands of unmoistened seed remained largely intact until heating had been prolonged for a considerable period.

(b) *Precautions for Preventing Deterioration During Storage.* An average boll of cotton contains about forty seeds. From the moment the boll bursts open at the stalk the seeds are subject to deterioration. Drying of the cottonseed at 160-220°F before ginning retards increase in F.F.A. of the stored seed. For safe storage, the moisture in the seed should be below 10-11%. In hot seasons, only seeds of low F.F.A. and upto 12.5% moisture should be stored in large quantities. The seeds of high F.F.A. (about 2.5% and above) should be stored in small units equipped with the best air-cooling facilities and at a temperature of about 60°F. Prime seeds and immature seeds, which could be distinguished by Chester's method,[3] should be stored separately. Otherwise, good oil from the good prime seeds will be contaminated with bad oil from immature seeds. Seeds which have undergone deterioration by storage are black in colour and yield oil much darker than that from field-damaged seeds.

The following chemical treatments would also be helpful, in addition to the above, in preventing deterioration:

(1) Subjecting the seeds to an atmosphere of gaseous ammonia. This also helps in improving the colour of the extracted oil.

(2) Spraying the seed with liquid ethylene chlorhydrin at a concentration of from 0.2 to 1.0% based on the dry weight of the seed.

(3) Using 5% by weight of sodium chloride for treatment of stored cottonseed, which results in improvement in the seed and derived products.[5] Colour of the oil was better than that produced from untreated seed of the same moisture content stored for the same length of time. Refining loss of such oil was lower than that of oil from untreated seed, oil yield and feed value of meal were unaffected, and quality of the hulls and lint were improved. The action of the salt was to extract moisture from the seeds, penetrate the seed

coat, and inhibit enzyme action within the seed. It is also observed that 12% sodium chloride inhibits respiration. Since salt is easily available and easy to incorporate, it is suggested that this method be experimented on for storing cottonseed prior to processing.

Precautions during Processing

In cooking cottonseed meats prior to expression, special attention has to be paid to maintain (1) proper moisture control of the meats, (2) temperature control, and (3) cooking time.

(a) *Moisture Control.* Uniform moisture control (11-12%) is essential for good press-room work. When meats are cooked to a lower moisture content, the material is crumbly and does not compact properly. There is high spillage from the edges of the formed cake and the meats do not flow in the press. This results in relatively poor expression of the oil. When the meats are cooked to a higher moisture content, the material is too fluid in the press, which produces excessive "footing" with poor expression of oil. High moisture content of cooked meals cause excessive strains within the press cloth during pressing, leading to cloth rupture and consequently high press-cloth costs.

(b) *Temperature Control.* The quality of cottonseed oil with respect to refining loss and colour can be controlled in part by regulating cooking temperature. Thornton has shown that it is desirable to heat the meats quickly to about 190°F and then humidify the meats with hot water to produce cottonseed oil with a low refining loss and light colour. Such oil has a relatively low phosphatide content.

(c) *Cooking Time.* To produce a good oil and meal having good colour, the cooking time should be as short as possible. Particularly when processing frost-bitten or immature seed, increased cooking time results in oil of higher refining loss. On prime meats, a longer cooking time is favoured to improve oil recovery. On high F.F.A. and damaged meats, a shorter cooking time is recommended to maintain the best possible meal colour.

Since cooking causes darkening of the oil and cake through a diffusion of cooking materials from the resin glands and also denatures the proteins, the above precautions would help in minimising these drawbacks.

In all the three types of seed damage stated above, the gossypol in the seeds gets converted to highly-coloured quinoid compounds. The expressed oils obtained by modern methods of processing involving preliminary cooking of seed usually contain very small amounts of gossypol, *i.e.*, "free gossypol." All the remaining gossypol gets converted to "bound gossypol." This is supported by the observations by Leah[6] that immediate refining of freshly-expressed oil results in a product in which little pigment fixation has occurred. On the other hand if the oil is not immediately refined after expression, fixation of the pigments occur, *i.e.*, pigments develop in the stored oil that cannot be removed by conventional refining and bleaching. The gossypol content of cottonseed oil is time-dependent. For example, 260 mg. of gossypol were added to 100 gm. of a crude hydraulic press oil; after one hour only 20 mg. could be recovered. This experiment was repeated with other samples of cottonseed oil obtained by different methods (Table I).

TABLE I

Gossypol Recovery after One Hour from the Time of its addition to Various Samples[6]

Description of Sample	Gossypol present initial %	Gossypol added %	Total Gossypol %	Gossypol recovered by alkali %
1. Refined, bleached and deodorized oil stored in deep freeze and not exposed to room atmosphere ...	0.002	0.090	0.092	0.092
2. Refined, bleached and deodorized oil stored at room temperature and exposed at room atmosphere ...	0.001	0.090	0.091	0.054
3. Crude screw-pressed oil	0.006	0.450	0.456	0.106
4. Crude hexane-extracted oil	0.067	0.140	0.207	0.111
5. Crude hydraulic-pressed oil	0.007	0.260	0.267	0.020

Secondary reactions occur in cottonseed oil in which the gossypol was lost to give rise to red colouration products which are not removed by alkali-refining and bleaching. This is well illustrated by the data in Table II.

TABLE II

Effect of Gossypol on Colour of Refined, Bleached and Deodorized Cottonseed Oil[6]

Storage conditions	Treatment of oil	Gossypol content (original) %	Grams of gossypol extracted by NaoH %	Lovibond colour (1-inch cell)	
				Yellow	Red
1. Original sample	None	0.003	0.002	5.0	1.1
2. Original sample	Gossypol added	0.555	0.550	35	2.4
3. Stored 63 days at −26°F	None	0.003	0.001	5	1.2
4. Stored 63 days at −26°F	Gossypol added	0.545	0.520	20	1.9
5. Stored 63 days at 98°F	None	0.002	0.0007	10	0.7
6. Stored 63 days at 98°F	Gossypol added	0.480	0.289	15	21.0

Gossypol was added to a refined, bleached and deodorized cottonseed oil that has been stored in the deep freeze and not exposed to atmosphere prior to the addition of gossypol, and portions were stored at 98°F and at -26°F. It will be noted that about 95.5% of the gossypol added to an oil which was stored at -26°F was recovered after 63 days, and only a slight increase of Lovibond red colour occurred. There was on the other hand a 40% loss of gossypol in the oil that was stored at 98°F for 63 days, and there was also a marked change in the red colour of the oil.

It is evident that secondary reactions are mainly responsible for colour deterioration. By analogy with this, it is quite possible that in the seed also, right from the time of cultivation to that of extraction, similar reactions would take place resulting in the transformation of "free gossypol" to "bound gossypol." Whatever gossypol is left unconverted to bound gossypol prior to the extraction of oil from the seeds finds its way to the crude oil produced. Indian cottonseed is characterised by a low gossypol content[7] and it occurs to the author that the dark colour of Indian oils despite low gossypol content might be due to these secondary changes.

Refining and Bleaching of Cottonseed Oil

A slight modification in the conventional method of refining and bleaching is suggested.

The crude oil may first be subjected to a mild bleaching with spent earth (*i.e.*, bleaching earth and carbon mixture which has been used once). By this treatment the colloidally suspended substances such as gums, resins and other degradation products present in the oil would get adsorbed in the filterpress mud. The filtered oil would be free from all surface-active agents present in the crude oil and also mainly responsible for the refining loss. The oil would also be lighter in colour. When such an oil is refined with alkali, the soap-stock will have a lighter colour and the refining loss will be less. Since spent earth would be always available in any refinery, this process would not cost any extra money; moreover the oil retention in the press-mud would be a minimum because it is a once-used bleaching agent.

It may be mentioned that gossypol in the free state helps to reduce refining loss. In fact, the addition of gossypol to expressed oils, in a concentration as low as 0.1%, has been reported to produce a lower refining loss because of the formation of more compact foots. This is further substantiated by the fact that refining loss of the oil obtained by the Russian Skipin method is much lower than that from hydraulic and screw-pressed oils. Skipin oil contains a large proportion of gossypol (0.8-1.2% of the weight of oil), compared to 0.05% in hydraulic-pressed oils. The low refining loss in the Skipin oils has been attributed to the high gossypol content of the oil.

Bleaching. It is worthwhile investigating the efficacy of bleaching earth and carbon for bleaching cottonseed oil.

According to Langmuir's theory of adsorption bleaching,[3] the free valency on the adsorbent would combine with the colour compounds to produce "complex salts." Bleaching with carbon is a physical phenomenon. Generally, most of these adsorption bleaching agents are efficient in removing the yellow colour of the oil, mainly due to carotenoids, which owe their colour to the presence of multiple conjugated double bonds. According to Langmuir's theory, the free valency of the activated bleaching earth would probably get attached to the conjugated bonds of carotenoid forming "complex salts." The adsorption of red colour due to the quinoid compounds in cottonseed oil would therefore be less efficient. It is suggested that admixture of bleaching clay and carbon with reducing agents like "hydros" would give the desired effect.

The pH of the bleaching clay and carbon have an important role in the efficiency of bleaching. A high pH above 9.5 or low pH below 4 are detrimental to colour removal.

This detrimental influence of a high pH is attributed to a catalytic action of certain alkaline chemicals in promoting oxidation. When the pH is low, particularly when sulphuric acid is used for pH adjustment, the film of acid on the surface of the adsorbent may react chemically with the oil and produce a darkening effect such as occurs when concentrated acid is used. The data in Tables III and IV help to illustrate the influence of pH on the bleaching efficiency.[9]

TABLE III

Treatment of Refined Cottonseed Oil Using 1% Activated Carbon Adjusted to Different pHs.

pH of active carbon	Lovibond colour, $2\frac{5}{8}$–inch cell		F.F.A.
	Yellow	Red	%
8.6	35	5.2	0.040
7.0	35	4.7	0.040
* 6.1	35	4.5	0.040
4.5	35	4.5	0.044
3.8	35	4.8	0.046
2.7	35	5.2	0.052
Original oil	35	7.2	0.044

* pH between 4.5 to 6.1 gave a better decolourisation than higher or lower pH.

TABLE IV

Decolourisation of Cottonseed Oil using 0.75% of same Clay adjusted to Different pHs

pH of clay	Lovibond colour, $2\frac{5}{8}$—inch cell	
	Yellow	Red
9.3	35	4.9
5.4	35	2.8
* 4.5	35	2.6
* 2.5	50	15.0
Original oil	35	6.6

* pH of 2.5 actually increased the colour of the bleached oil, whereas a pH of 4.0 was efficient.

The important conclusion from these data is that manufacturers of bleaching earth and carbon should take into consideration the pH of the material. Probably some instances of colour reversion of the bleached cottonseed oil may be due to low pH.

Solvent Extraction and Oilcake

Before concluding, a word about solvent-extracted cottonseed oil needs mention. While solvent extraction may help to increase the output of cottonseed oil, the colour of the oil may not be good because the pigments are also extracted along with the oil. These pigments in turn undergo degradation resulting in colour fixation. The oil so obtained is very difficult to refine and bleach. The following extract from Bailey[10] emphasises this aspect: "It is generally considered that to be efficient, commercial solvent extraction must reduce oil content of the dry solid residue to less than 1.0% and preferably to about 0.5%. There is undoubtedly some fallacy in the common belief that the inefficiency of the extraction is to be judged simply by the amount of oil remaining in the meal. This last portions of the "oil" or petroleum ether-soluble material in the meal are in considerable measure not oil at all, but phosphatides and other non-glyceride impurities. Bull and Hopper have reported a phosphatide content of 18.62% in the last 1.1% of the material extracted from a sample of soyabean flakes with commercial hexane at 40°C. It is difficult to believe that the addition of such material to a good oil could fail to have a decidedly adverse effect on the refining loss. It appears entirely possible that such adverse effect might well serve to more than counterbalance the increased oil yield, and thus actually reduce the amount of material recoverable as refined oil. Thus far little attention has been paid to the efficiency of oil seed extraction in relation to the yield and quality of the refined oil; yet the latter is the true measure of efficiency."

The vanaspati industry is keen on consuming as much of cottonseed oil as would be available; however, this may not be possible unless oil of good quality is made available. It is therefore a matter of conjecture as to how far solvent extraction would be able to supply cottonseed oil of acceptable standard, and thereby partially fill the present shortage of cottonseed oil. In this connection, it may be pointed out that gossypol in the free state combines with soluble iron salts to yield iron-gossypol complex. This reaction is made use of to remove the toxicity due to "free gossypol" in cottonseed meal. Hence, if the question of toxicity of cottonseed meal due to free gossypol is a deterrent in consuming the meal as cattle-fodder, the gossypol can be deactivated by the above method.

Conclusion

A co-ordinated effort by Government and private enterprise is bound to help in exploiting cottonseed and its by-products to the maximum advantage. It is suggested that special supervision be made during cultivation of the crop to prevent field damage to seeds. At the time of storing seeds, precautions need to be taken not to mix up prime and immature seeds. These should be processed separately and the oils so obtained refined without delay. Refining standards may be set up on the lines of the A.O.C.S. Methods. With such scrutinising care, we should not have any difficulty in obtaining cottonseed oil as good as that produced in America. Our salvation, as far as this industry is concerned, depends on manufacturing a high-grade oil, and not just cottonseed oil of any quality.

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DISCUSSIONS

Discussion Leader: Dr. K. S. CHARI,
Regional Research Laboratory, Hyderabad

Paper 1

K. S. Murti. The cost of linters as reported is high and under the circumstances reported, may not be economical. Certain items included in the costing, *e.g.*, supervision, depreciation on machines, royalty, etc., are high. The yield of linters reported is low. On a similar seed, the Oil Technological Institute, Anantapur has recovered about 6.1-6.6% linters, leaving about 2.5% on the seed. The yield of hulls reported is low and the yield of meats abnormally high. The usual yield of hulls in our pilot-plant work is between 29.0 and 39.4% and that of meats between 47.9 and 52.5% with an average value of 50.1% for American-variety seed.

K. S. Srinivas. Sirsilk is the largest user of linters in India and the quality of linters is of great importance. It is not clear why linters containing as high as 3% ash should be used for obtaining bleached linters. The uses of first and second-cut linters are not stated.

C. R. Das. Has any work been done regarding the effect of pH during the cooking of meats on the yield and quality of oil? Has any work on the storage of meats been done?

T. V. Subba Rao. The cost estimate shown in the paper is not clear. The labour rate shown in the calculation is low and dearness allowance has not been taken into consideration. It often becomes necessary for technical people in the industry to rework the cost estimates presented by some of these laboratories or the N.R.D.C., with due alterations in the rates for the above. It is also the general experience that steam costs given in such cost estimates are often not realistic.

Burhanuddin Hussain. Sirsilk uses a large quantity of linters for rayon manufacture, but the linters produced in Andhra Pradesh are reported to be unsuitable for rayon manufacture. Part of their requirement is met from Hubli, but the rest is imported from abroad. Can we produce good-quality linters suitable for the rayon industry.

J. M. Shah. Disposal of cotton linters is one of the biggest problems of the cottonseed-crushing industry and in a number of factories, stocks have accumulated for want of a market. Some solution should be found for the proper disposal of linters.

B. P. Maheshwari. The views expressed by the previous speaker are quite correct. Cottonseed crushers are helpless in the disposal of linters and consideration should be given by the National Laboratories to this and other important problems. Not a single bale of linters has gone out of our godown during the last year, since they have been rejected by the only consumer in the country. Considerable time and thought should be given to this important problem of the disposal of linters.

V. K. Parikh. Unless 8% of linters are cut during the delinting of cottonseed, the process is not economic. In India, there is no market for the first-cut linters which would be produced if double cutting were to be adopted for delinting. Second-cut linters will no doubt be bought by Sirsilk but they require linters of high α-cellulose content and of low ash content. It is possible to achieve these conditions only if the process is economical.

K. S. Chari (replying). The results reported are actual figures obtained in processing about 55 tons of seeds in the pilot-plant at the laboratory, based on the local rates for labour, etc., which may not represent the labour rates in Bombay or any other place. The costing should not be applied *in toto* to an industry in Bombay, but is meant to form the basis for estimation of the economics of the industry.

In the calculation of indirect costs like depreciation, the actual cost of machinery and buildings are taken into consideration and the usual figure for depreciation is used. The figure only appears to be high, since the cost of the pilot-plant is high.

The royalty of 10% shown is the actual figure charged to the party which agreed to get the seed processed under that condition. This figure for royalty is not usual while estimating the economics of the process.

The yield of linters as reported is low, since, as pointed out in the paper itself, the adjustments for delinting are made so that the seeds are not damaged during delinting. It is possible to cut more linters, but the seed will be damaged and the linters will be contaminated with hull-pepper.

The yields of hulls reported are low since a portion of fine hulls passes through the perforated drum of the Rotating Drums Tailings Beater and joins the stream of meats. For the same reason, the yield of meats reported is higher than normal.

The ash content of linters is high because there is no lint-cleaning machine in the set-up of the pilot-plant existing in the Laboratory. A lint-cleaning machine is being procured and after its installation, the ash content of linters could be brought down considerably.

No work on the control of pH during the cooking of meats has been done in this laboratory but this should be done. Some additives at the stage of cooking have an influence on the quality of expelled oil.

No work has been done here on the storage of meats and although the application of such a study is limited, it should be taken up.

Linters from Andhra Pradesh are not preferred because of their low quality. If suitable lint-cleaning and baling machines are used and the linters are cut in two stages, there is no reason why the linters produced in Andhra Pradesh should not be used for rayon industry.

The work reported here is only a beginning, and extensive pilot-plant work should be done on the different types of cottonseed grown in various parts of India, and the economics studied.

The Regional Research Laboratory, Hyderabad is well aware of the various problems facing the cottonseed industry. Some years ago, a survey of the cottonseed industry was started and a few plants visited by a team of research workers. The problems facing the industries visited were personally discussed, and wherever this was possible some suggestions were given. Some of the problems which needed investigation were noted with the intention of incorporating them in the programme of work of the laboratory. That was only a beginning. If the visits are extended to the industry in all parts of India, a clear picture of the industry and its problems can be had.

C. R. Das. Some work on the control of pH during cooking of meats and its relation to the quality of oil is reported by American workers (W. H. King *et al.*, J. Amer. Oil Chem. Soc., 1956, *33*, 71). Control of pH had a great influence on quality of oil and meal. At low pH, the cake had a high gossypol content, and at high pH, the oil gave a low refining loss.

Paper 2

C. R. Das. I would like to give some practical tests for oil mill operation.

1. *Cooking of Cottonseed Meats.* Steam is injected into the feed line of meats before the cooker. Moisture is adjusted to about 12% in the meats and later on reduced to about 6% after cooking.

Properly-cooked meats readily give up their oil when squeezed in the hand or between the fingers. They should have a slight orange colour without any tinge of green. They should have a slightly sweet smell, with no tannin odour.

2. *Foots Production.* The barrels of the expellers should be checked periodically to gauge the degree of foots production as well as to make sure that no foots are accumulating in or about the expeller barrels. The screening tank should be observed at least at hourly intervals. An increase in foots produced may indicate too high a moisture content in the meats at the downspout of the expeller. A production of the combined screening tank foots and filter foots equal to one pound of foots for 100 pounds of material fed can be assumed to be a good low foots-production value.

3. *Expeller Cake Weighing.* Weighings of the cake from each expeller is carried out by collecting the cake for three minutes and weighing. This permits a check on the capacity of the entire operation as well as a check on the capacity of each individual expeller.

B. P. Maheswari. In India, there is no market for the decorticated cake, as the price is not based on the protein content. The demand is only for undecorticated cake and high-capacity expellers should be developed for expelling the whole seed.

T. V. Subba Rao. During the expeller crushing of oilseeds either by single stage or double stage, control of moisture and temperature is very important. The foreman cannot afford to wait for his adjustments till the laboratory reports are received and the present methods of moisture and oil determination are time-consuming. Are any of the Indian crushers using the quick moisture and oil-determination instruments recently developed abroad and if so with what practical advantage?

C. R. Das. There are some instruments which can determine the moisture content in a few minutes. One is in use at D.C.M. for determination of moisture based on the ultraviolet-absorption. Moisture-testing units are also supplied by Sargent & Co., and are usually advertised in each issue of the Journal of the American Oil Chemists' Society.

K. S. Murti. Oil and moisture are analysed in the U.S.A., and Germany in 5-10 minutes and instruments for such measurements are available.

S. A. Saletore. The paper appears to be one-sided, as it only shows the advantages of high-speed expelling. It is true that the residual oil content of cake is low if a Super-Duo expeller is used, but how do the economics of ordinary and Super-Duo expellers compare under Indian conditions, considering the high cost of the latter and the higher wear and tear caused by high-speed operation?

The other aspect to be clarified is the comparative economics of expelling in the Super-Duo expeller and of direct solvent-extraction of cottonseed meats.

N. Bhojraj Naidu. Has any effort been made to detoxify the gossypol in the cake and oil?

K. S. Murti. It has been found by us in the laboratory that by adding 10-12% moisture and heating at 225-245°F to reduce the moisture to 3-4%, the gossypol content of oil obtained is very low.

V. K. Parikh. Using a screw press, the cooking was done with 9-12% moisture at 225-245°F The oil was no doubt of better colour but the cake was very brown. Its odour was of a roasted kind not acceptable in this country, though such a cake might find a sale in the U.S.A.

G. V. Sirur. If more oil is to be expelled from the meats, greater pressure is to be applied. This has been recognised in the U.S.A. and the expellers have been gradually raised from 80 H.P. to 105 H.P. for the recent Anderson 55 expeller. Increase of pressure results in added problems in the selection of suitable materials of suitable strength. The ultimate aims are to get the best yield of oil, high capacity and low oil content of cake.

If the expeller is speeded up, the wear and tear is more, but the capacity is considerably increased. If the capacity is doubled, the overheads are halved. If the meats are not cooked and dried properly, the above results are not achieved. However, if the meats are cooked and dried to the optimum conditions, the gossypol is bound in the cake and better oil is obtained.

As regards the economics, one has to bear in mind that even an increase of 0.5% in yield on a 100-ton per day plant makes a considerable difference to the economy. This is the reason for the development of foreign expellers of high pressure and high capacity.

K. S. Chari. The comparative economics of expelling and direct solvent-extraction are given in a paper by Depmer. It is pointed out that prepressing of the meats with a screw press followed by solvent-extraction is more economical than direct solvent-extraction of the meats. The residual oil in the solvent-extracted cake is also high if directly solvent-extracted.

PAPER 3

There was no discussion on this Paper

PAPERS 4, 5 & 6

K. S. Murti. The authors of the paper 4 are to be congratulated for the excellent work reported. However, some generalisations require some clarifications. It is mentioned that storage in pyramidal heaps is better than in gunny bags; but from the data reported, there does not appear to be any difference. Normally, aeration should be better in seeds stored in gunny bags than in heaps. Other than the data reported, is there any further data to support such a statement?

It is suggested that it is better to store crude oil instead of seed. This is not very practical, as the seed is a seasonal crop and storage of seed is inevitable.

Thiocyanogen values have been shown by Hilditch and Murti, and also by others, to be very undependable and also time-consuming.

Is there any basis for the statement that oils rich in gossypol will colour-fix to a greater extent?

J. M. Shah. Regarding the fixing of colour for washed oil, I would like to draw the attention of the members present in the house to some aspects. Generally cottonseed oil is sold in the foreign market on the basis of a colour of 35 (Y + 10R). Certain exporters and manufacturers use bleached earth or activated carbon in order to improve colour. Foreign buyers find that colour fixation takes place as a result of the use of bleached earth, and they find that they obtain a very high colour after bleaching the oil, whereas if the oil is washed with caustic soda solution this colour fixation does not take place.

W. J. H. Bendixsohn. In order to reduce the deterioration of seed during storage, it is better to store seed in heaps than in bags, as the latter offers greater access to the variations in the relative humidity of air.

K. T. Achaya. Regarding the washing and refining of the oil, this will be taken up in another section, when the problem will be dealt with in detail.

As regards the storage of crude oil instead of seed, the advantages are that the bulk to be handled is considerably reduced and that the oil is not subjected to deterioration to the same extent as the seed. In view of these, storing oil rather than seed may be considered though colour fixation is rapid.

Regarding aeration of seed stacked in pyramidal heaps and in bags, while there may be better aeration between the bags, there is not as much aeration between the individual seeds as in heap storage. In the results reported the difference is not very significant, but the generalisation made is based on additional data given in the final report of the scheme on storage studies of cottonseed and its oil, put out by the Regional Research Laboratory, Hyderabad.

S. S. Ramaswamy. What is the limit of stacking the bags? Cannot the seed be stored in bins like other grains?

K. S. Chari. Cottonseed is stored in silos in the U.S.A., and proper aeration conditions are maintained. In India, the seeds are generally stored in heaps or in bags. The seed can be stored with advantage in silos. Regarding the details of how the seed is stored in India, the final report of the work on storage at this Laboratory may be referred to, which gives some pictures of the stored heaps.

K. S. Murti. Regarding the storage of cottonseed meats, no work has been done here, though the problem is of importance. It cannot be stored for more than a week as the F.F.A. increases enormously; the F.F.A. was observed to increase by 1-1.5 units during storage overnight. If the rolled flakes are stored, the increase in the F.F.A. would be even higher.

J. G. Kane (*communicated*). The work in paper 6 relates only to one oil sample picked at random. Therefore, it may not be correct to draw any generalisations from the results obtained. Since the history of the seed and the oil greatly influence the refining characteristics of the oil, it would be interesting to extend this work to a large number of samples of cottonseed oil obtained under different processing conditions and refined in different ways.

PAPER 7

K. S. Chari. The author of the paper is not present but Shri T. V. Subba Rao has agreed to reply to any points that are likely to be raised during the discussion.

T. V. Subba Rao. (Summarised the paper and presented its salient points).

C. R. Das. In the U.S.A. work is being done on the development of seed free from gossypol. This work is of great importance in view of the complications created by its presence in seed. The feeding problem will also be solved if the seed is free from gossypol.

J. M. Shah. Normally the price difference between decorticated and undecorticated cake is about £6-7, *i.e.*, Rs. 90 per ton, but in the local market consumers do not bother much about the quality of the cake or whether it is decorticated or undecorticated. Of course there is a premium for decorticated cake, but the difference is only upto Rs. 30 per ton, whereas actually the cost is much higher. In the domestic market consumers go by the green colour of the cake and do not care to know its protein content. If, in order to obtain higher percentage of oil, the cake is pressed more it gets darker in colour and this cake is not easily saleable in the market. Therefore unless the consumer is educated to know the value of protein contents, the seller has to bear in mind what is liked by the consumer and has to aim more for colour than for protein percentage of the cake. Another point of great importance is the disposal of linters. There are a number of factories who have not been able to dispose of even one bale of linters in the Indian market because there is only one buyer. It is the duty of that particular buyer to give encouragement to the local producers of linters.

SECTION III

SOLVENT EXTRACTION

Discussion Leader: Shri H. V. Parekh,
Tata Oil Mills Co. Ltd.,
Bombay.

1. SOLVENT EXTRACTION OF COTTONSEED OIL IN INDIA

By

H. V. PAREKH

(*Bhavnagar Chemical Works Ltd., Vartej*)*

Direct solvent extraction of cottonseed may well be adopted for Indian cottonseeds low in oil content. Use of whole cottonseed as cattlefeed should be discouraged, since the high percentage of oil in cottonseed is not fully utilised by animals. A mixture of deoiled meal and whole cottonseed, containing about 4-5% oil and a higher protein percentage than that in raw cottonseed should be considered a good cattlefeed in India. Excess oil going as waste in raw cottonseed should be recovered in such a manner that the resulting meal contains a high percentage of unmodified proteins. Cottonseed oil is considered good for making vanaspati. As far as possible, solvent extraction of cottonseed oil should be carried out on a co-operative basis.

Introduction

There is hardly any chemical industry which had to struggle for about 45 years to plant its roots in Indian soil. The first solvent plant was imported into this country in 1905; but it was only after the starting of the plant at the Bhavnagar Chemical Works Ltd., Vartej in 1950, that the solvent-extraction industry was recognized in its proper perspective.

At present about 20 plants, having a total daily capacity of approximately 1050 tons, are working in India. Two continuous plants having 150 tons/day capacity are under erection. Besides this, active inquiry is going on for 10-15 plants; but because no foreign exchange is available, it is doubtful if many plants will come up in the near future. It is gratifying to note that East Germany is offering 3-4 solvent plants in rupee currency. Although the price quoted by the East German Government is high compared to the ruling price for equivalent plant in Europe, it is likely that all plants offered in India will soon be purchased by industrialists as no exchange is necessary.

The nine continuous plants that are at present working have an aggregate daily capacity of 550-600 tons. The modern trend in India is definitely to go in only for continuous plant and not to encourage semi-continuous units designed and fabricated locally.

The target fixed for the Second Five-Year Plan is 8 lakh tons per annum in terms of oilcakes. Considering the achievement of industry so far, it is doubtful if more than 60 per cent of the figure set for the Plan years can be fulfilled.

The Solvent Oil Extractors' Association has been formed in 1955 with the blessing of the Hon'ble Shri Manubhai M. Shah, then Finance Minister of Saurashtra (at present Minister for Industry, Government of India) in order that problems of the industry may be well represented to the Government of India and that necessary help may be extended to various State Governments to fulfil their targets.

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* *Present Address: Tata Oil Mills Co., Ltd., Bombay.*

Almost all solvent plants functioning in this country are processing more or less exclusively groundnut oilcake; very rarely mahua oil, castor oil and *khakan* fat are extracted in these plants.

Government of India have kept the export of deoiled cottonseed meal open on a long-term basis; but so far no plant has been interested to treat cottonseed. There are certain problems both of commercial and technical nature which require solution before extraction of cottonseed oil in India becomes an established fact.

Upto World War II, Germany was the recognized leader in solvent-extraction equipment and processing, but after the war the U.S.A. has definitely taken the lead and as far as cottonseed oil extraction is concerned, it is the only country which can be looked to for technical help by India. Up to June 1946, no solvent plant was working in U.S.A. for cottonseed oil on a commercial basis. Only in the last decade has cottonseed oil extraction gained ground in the States. The modern trend in that country appears to be to prefer direct extraction of cottonseed oil to a forepressing-cum-extraction operation.

Processing of Cottonseed

The annual production of cottonseed in India is placed at 1.7 million tons; out of this 75% is of the *desi* variety and 25% is American-type.

Since on an average the oil content of Indian cottonseed is lower than that grown in the States, it is assumed without going into much detail that direct extraction of oil will prove to be quite an economical proposition.

Free gossypol content and protein solubility in dilute alkali are two chemical indices to measure or rate the toxicity and nutritive value of cottonseed meals. It may be noted that these two indices are not absolute measures of meal quality and efforts are under way to find better chemical indices. At the moment these are the best available methods for technologists engaged in the business.

Chemists recognize gossypol in two forms, "free" and "bound." By "bound" is meant gossypol that has been combined chemically with some component of the meal. In this form it is generally considered to be harmless.

Traditionally whole cottonseed has been fed to cattle and farm animals in India with satisfactory results. In other words, our animals seem to have developed immunity to the "free" gossypol content in seeds. However, in so far as chick, broiler and swine rations are concerned, the picture is different. It has been found in the U.S.A. that for use in unrestricted proportions in a balanced diet for chicks, broilers and swine, it is desirable that deoiled meals have 0.04 per cent or less of free gossypol and a solubility in 0.02 N NaOH solution of 75 per cent or more.

The steps that require attention for successful extraction of cottonseeds are planned unit processes in pretreatment and extraction sections. It may be remarked that preliminary operations are of utmost importance and hence due regard should be paid to them right from the conceiving period of the industry.

The following processes are considered essential for the recovery of quality oil from cottonseed and also for production of deoiled meal of excellent nutritive value:

(a) *Delinting.* This is done after ginning to remove fuzzy cotton from the upper coat of the seed. In general, the cost of delinting is compensated for by the higher price realised for lint cotton.

(b) *Decorticating.* This operation is carried out to separate meats from hulls, which is generally considered useless for oil recovery. Lint and hull account for 50 per cent of the total weight. Dehulling and delinting processes reduce cost of production and increase the capacity of the solvent plant.

(c) *Conditioning and Tempering.* The purpose behind this process is to assist the subsequent operation of rolling or flaking. Although carried out mainly to get better oil extraction, conditioning and tempering under proper conditions will do much to help the rolls to rupture or break open the pigment glands.

(d) *Flaking.* Rolling or flaking, if carried out at a temperature of 120°F or lower, will have little or no effect in reducing alkali solubility. But this operation has a profound effect on gland breakage and the final free gossypol value of the meal.

(e) *Cooking.* In the cooking operation we have the first chance to do a real job of binding the gossypol. Unfortunately however, it is very easy in this operation to reduce the alkali solubility to values considerably lower than 75 per cent.

It must be borne in mind that any operation following cooking, such as meal desolventization, may result in further reduction of alkali solubility. For this reason, the cooking should be carried out under such conditions that the alkali solubility remains higher than 75 per cent after this process.

Considering the fact that free gossypol to a certain extent is not considered objectionable in India, the cooking operation after flaking is not considered important. This may be conveniently omitted altogether.

(f) *Mechanics of Extraction.* Solvent-extraction process in its simplest terms means the recovery of oil from oil-bearing materials by making use of a suitable type of volatile solvent. The guiding principle behind continuous plant is that the solvent should be passed through the travelling mass of the oil-bearing material continuously in a countercurrent and/or concurrent direction. Continuous extractors in horizontal, inclined and vertical positions have been proposed, while the solvent mass moves through the extractor by gravity or by means of a pump. Continuous extractors developed so far and applied commercially may be roughly classified as follows:

(i) Extractors conveying the oil-bearing material through a solvent bath by means of horizontal, vertical or inclined screw conveyors. This group includes (a) Hildebrandt, (b) Krupp, (c) B.M.A., (d) Egrot & Grange, (e) Ford, and (f) Detrex.

(ii) Extractors conveying the oil-bearing material through a solvent bath by means of other than screw conveyors, including (a) Bonotto, (b) Allis-Chalmers, (c) Anderson, (d) Miag, (e) Kennedy, (f) Iowa State system, and (g) Gaito-Buhler.

(iii) Extractors with screw presses for solvent removal, such as the Fourth Extractor.

(iv) Extractors with various transporting devices, in which the material is exposed to a solvent rain, like (a) Tyca, (b) De Smet, (c) Rotocel, and (d) Rosedown Merz.

(v) Basket extractors in horizontal, vertical or combined arrangement in which the material is exposed to a solvent rain, or remains in a solvent bath, including (a) Bollmann system, (b) French Oil Mill extractor, either Vertical or Horizontal and Rectangular, (c) Lurgi, either Vertical or Horizontal, and (d) Bamag-Manning extractor, either Vertical or Horizontal.

(vi) Other types of extractors, such as (a) Sherwin-Williams, and (b) "Filtration-extraction."

(g) *Desolventizing and Toasting.* The most successful of several improvements are the superheated vapour desolventizer and the vertical cooker desolventizer, which is universally known as DT (Desolventizer Toaster). The DT uses sparging steam in varying quantities to supplement indirect heat to desolventize flakes, followed by such additional heat treatment or toasting as is desired.

The new combination Desolventizer and Toaster of the French Oil Mill Machinery Co., has the following advantages:

(i) Improved solvent recovery.

(ii) Finished meal as discharged is guaranteed to contain no solvent.

(iii) Solvent vapour scrubbed by solvent-wet flakes, making the best type of vapour scrubber.

(iv) Minimum fouling of condensers.

(v) Proper humidification of meal during desolventization (separate humidifier not necessary).

(vi) Steam economy by utilizing steam for both processes.

(vii) Production of white, extracted flakes for industrial uses or for protein production.

It is claimed that this development alone cuts 25% from previous solvent plant costs. Results from processor plants are stated to show solvent losses cut by 50% and even upto 75% of previous losses.

Toasting is considered good for cottonseed meal intended for cattlefeed.

Besides the above processes, due attention should be paid to unit operations, such as distillation of miscella and stripping of solvent vapour from out-going gases with the help of an efficient refrigerating system.

Mention should be made about refining of cottonseed oil in the stage of miscella, which may prove to be more economical than neutralization of crude extracted oil.

The usual specifications for deoiled cottonseed meal in the U.S.A. are less than 0.04% free gossypol and more than 75% protein solubility in 0.02% NaOH.

Selection of Solvent–Extraction Unit

A critical study of different solvent-extraction plants reveals the fact that all the units marketed by well-known firms are quite safe to work with; but in actual practice hardly four or five firms are able to submit the best possible quotations with the accompanying technical services and "know-how" that would merit serious consideration in India.

In the first place, it is completely out-of-date to consider quotations for the batch unit. This type of plant appears to be very uneconomical in working and the fire and health hazards involved in the process are quite great.

Semi-continuous units are not known to be working in the U.S.A., on common oilseeds. These units were developed in Europe after World War I; but at present there is a definite indication that this process of extraction is fast becoming obsolete in Europe and in other parts of the world, the main reason being the fact that continuous plants down to a capacity of 25-30 tons per day are available at a reasonable price.

While selecting the continuous unit, one important factor should be borne in mind for the efficient and rapid extraction of oil-bearing materials: there should be a suitable arrangement for the replacement of the oil in the meal cell by miscella of continuously weaker strength and finally by pure solvent.

The continuous solvent-extraction plants available may roughly be divided into two categories, *viz.*, Submerged-type, and Percolation-type.

In the submerged-type, the soaking of the meal is done by passing flakes into a liquid bath. In this case, both the meal and the solvent are moving continuously in a counter-current direction to one another.

In the percolation system, the meal is contained either in a basket or on an endless belt conveyor with false bottoms, and the solvent is sprayed over the meal. The receptacles which contain the meal move slowly and continuously, while the liquid drains down from the perforated bottoms. The flow of solvent may be in a counter-current direction, or it may be counter-current in one section and concurrent in the other section of the equipment.

The advantages claimed in the submerged-type are:

(a) Each meal particle is completely wetted.

(b) Time of extraction is less than in the percolation system.

(c) Residual oil left in the final deoiled meal is low.

The main disadvantages in practice appear to be:

(a) The requirements for a complete and exact pre-treatment section.

(b) High-capacity efficient filters, since it is more than likely that a large amount of 'fines' will be coming up in the full miscella.

In the percolation system, there are no particular disadvantages, and the advantages to be achieved are:

(a) The meal itself works as an excellent filtering medium, so that in the latest type of units, working on the percolation system, no filters are necessary for the full miscella.
(b) The process is very much simplified due to the elimination of filters.
(c) It is possible to get highly concentrated miscella in the process.

Examining the modern trend in the U.S.A. and Europe, it may be said with confidence that the solvent-extraction plant working on the percolation system is to be preferred to the submerged-type when all other factors weigh equal in importance.

Problems in India

Apart from technical difficulties, which have been dealt with elsewhere, the main problems are the disposal of meal and of cottonseed oil at the right prices.

(a) Meal

The first and foremost problem for smooth working of solvent-extraction plant is an assured market for deoiled meal at an economical price either in India or in foreign countries.

Since cottonseed cake sells on a protein plus oil basis in the London Market, it is always likely that deoiled meal will command a much lower price than Indian groundnut cake of extraction 50%; strangely enough the ruling price of whole cottonseed in India is very high compared to that of groundnut meal. Under these circumstances, it is advisable to develop a home market and to think of exporting meal only at a later stage.

In order to give needed impetus to this new type of industry, it is imperative that deoiled meal should fetch a price almost equal to the ruling price of whole cottonseed in India.

The 15-20% of oil present in whole cottonseed is considered too high for suitability as cattlefeed. 4-5% oil in the final deoiled meal should be considered right for every type of animal food in India. In other words, a mixture of three parts of deoiled meal, containing about 1% oil and all the hull recovered from the decorticating process, and one part of whole cottonseed (if desired only delinted), should command approximately the same price as the ruling market rate for cottonseed. This mixture will prove to be more useful than whole cottonseed because of the following advantages:

1. Free gossypol is reduced to a very great extent.
2. On a weight-for-weight basis, more protein is available than from cottonseed.
3. Superfluous oil in cottonseed is recovered for human consumption.
4. The desolventization and toasting operation renders the proteins in a form most suitable for cattle-feeding purposes.

Decorticated deoiled meal will be very high in protein percentage. This meal if processed under strict hygienic conditions can be well utilized for human food.

If the solvent-extraction process has been applied to cottonseed which has not been subjected to fore-pressing, the deoiled meal will contain proteins in a highly unmodified state and thus is best suited for industrial recovery of cottonseed proteins.

(b) Oil

Refined cottonseed oil is well suited for human food, almost in the same manner as refined groundnut oil. Studies in the processing and utilization of cottonseed oil for edible purposes, carried out under the auspices of the Council of Scientific and Industrial Research by the Vanaspati Research Advisory Committee in 1952-57, have shown that cottonseed oil can be adopted for making Vanaspati. At present Vanaspati manufacturers in India are using 2·5% cottonseed oil in their products. It is likely that by the end of 1960, the percentage of cottonseed oil to be mixed with other vegetable oils will be raised to a 10 per cent level.

Solvent-extracted oil after due refining may also be utilized by the paint and varnish industry of India.

It is likely that in the initial stage, cottonseed oil will fetch a low price, but ultimately this oil will be at par with the groundnut oil ruling rate in India.

Although the market for cottonseed oil is rather limited, Government of India have kept its export open so that if the home-market is saturated, an outlet is provided for the surplus quantity manufactured in this country.

The problem of disposal of oil is not as difficult as the market for deoiled meal in India.

Working of Plant on Co–operative Basis

India has a long history of original co-operative efforts in the field of agriculture, industry and finance and is basically inclined towards the co-operative movement.

At present quite a number of sugar factories are coming up on a co-operative basis in India.

It is high time that Government devote their attention to the development of other industries on a co-operative basis, having agricultural products as raw materials. Next to sugarcane, oilseeds cultivation in India deserves due consideration for exploitation on a co-operative industrial basis. It is interesting to note that in the U.S.A., a very big solvent-extraction plant is working on a co-operative basis for direct extraction of soya bean oil. There are 39 co-operative societies who are members of this "North Iowa Co-operative Processing Association."

In recent years ginning and pressing of cotton is being carried out on a co-operative basis in some parts of India. This is a move in the right direction. Government as far as possible should give preference to such societies in granting licenses to put up solvent-extraction plants for cottonseed.

The crop being very seasonal in nature, it is generally not possible for a solvent-extraction plant to work on cottonseed oil for more than 4-6 months in a year. Thus the plant selected should be quite versatile in nature and alternative oil-bearing raw materials must be available for off-season processing. For economical running of the plant, working should be almost 300 days in a year.

2. SOLUBILITY OF COTTONSEED OIL IN ETHYL ALCOHOL

By

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Results obtained in a special solubility-determination apparatus for the solubility of crude and refined cottonseed oil in alcohol of concentrations 90-99.94% are compared with earlier results by other methods, and shown to be generally more accurate.

Alcohol as Solvent

The type of solvent used for the extraction of vegetable oils plays an important role in the economy of the solvent-extraction industry. Ethyl alcohol is one of the good indigenously-available solvents for the extraction industry, its main advantages being its low boiling point, low specific heat, low specific gravity and low latent heat of vapourisation. It is non-toxic and non-corrosive. Its main drawback is solubility in water.

With the notable exception of castor oil, most vegetable oils are sparingly soluble in ethyl alcohol under normal temperatures. The solubility increases with rise in temperature, and the oils are completely miscible in absolute alcohol at about 70°C.

Solubility of Cottonseed Oil in Alcohol

A rational approach to the design of an efficient extraction unit to extract vegetable oils from oleaginous materials requires a knowledge of the solubilities of vegetable oils in the proposed solvent.

Cottonseed oil solubilities in 95% ethanol have been reported by Sato, Inaba and Kitagawa[1] using the seal-tube method. Harris and co-workers[2] have determined the solubility data for refined cottonseed oil by the cloud-point method using a three-necked flask. An improved seal-tube method was used by Magne and Skau[3] using a glass bead in the seal tube for better mixing of refined cottonseed oil and alcohol. Rama Kant Rao *et al.*[4] have described a solubility-determination apparatus and have reported data for the solubility of crude cottonseed oil in 90 and 98% alcohol. The apparatus described appears to be more satisfactory than the others and the present investigation was taken up to make a complete study of solubility of cottonseed oil in ethanol of various concentrations and at various temperatures.

Apparatus and Results

The apparatus used and the technique adopted have previously been described in detail.[4,5] The characteristics of the refined cottonseed oil used are shown in Table I. The saturation solubility data obtained are shown in Table II and in Figs. 1 and 2.

It is seen that the solubility of crude cottonseed oil in 98% ethanol is more than the solubility of refined oil in 99.94% alcohol, probably due to the presence of free fatty acids

TABLE I

Characteristics of Cottonseed Oil

Sl. No.	Characteristics	Sample	Usual range
1.	Colour (Lovibond, 0.25-inch cell)	0.0Y+2.0R	
2.	Specific gravity d_{4}^{30}	0.9108	0.910—0.918
3.	Refractive index at 25°C	1.4753	...
4.	Free fatty acids %	1.0	1.9—0.6
5.	Saponification value	197.4	190—198
6.	Iodine value	108.3	100—116

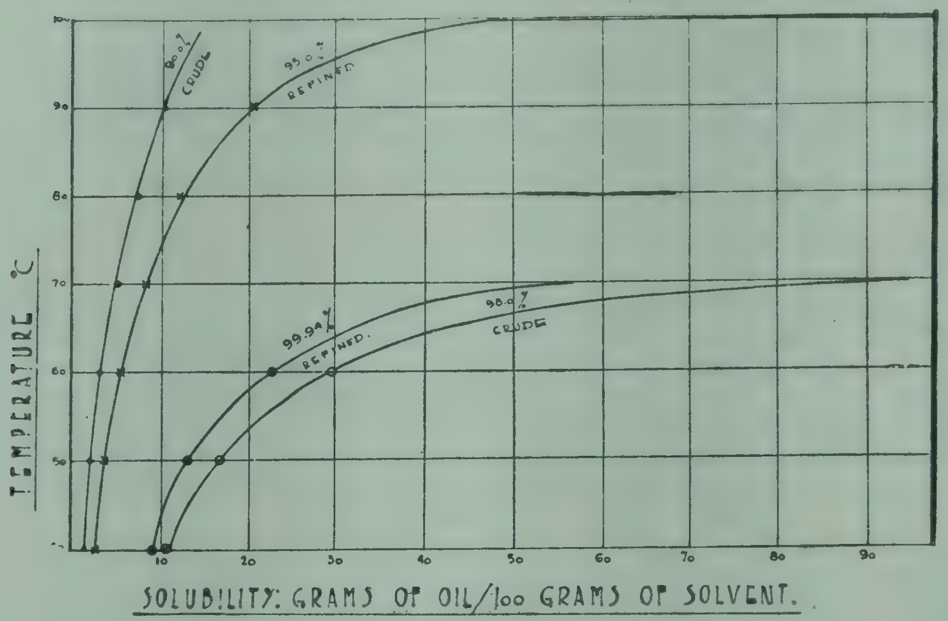
TABLE II

Saturation Solubilities of Cottonseed Oil in Aqueous Solutions of Alcohol

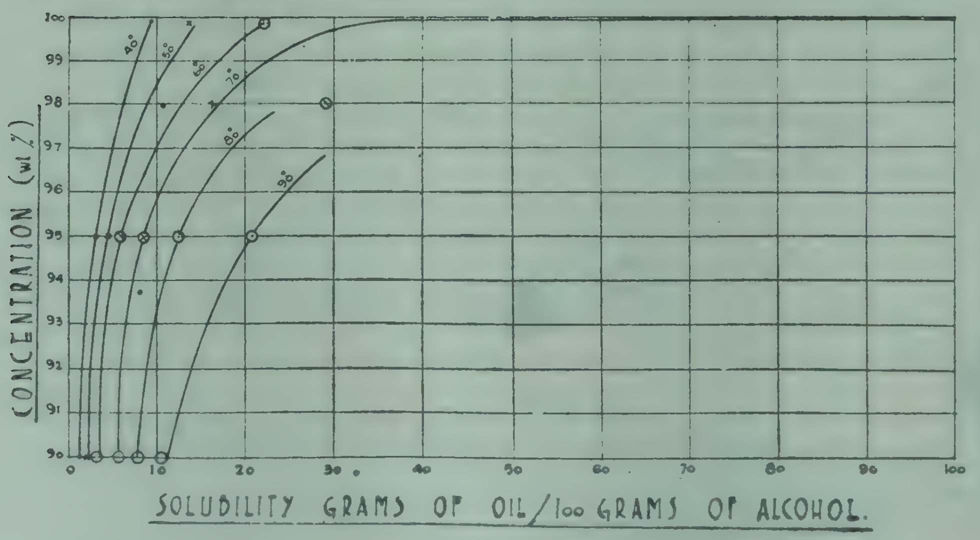
Concentration of alcohol (by wt.)	Ratio of oil and alcohol by volume	Saturation solubilities expressed as gms. of oil/100 gms. of alcohol						
		40°C	50°C	60°C	70°C	80°C	90°C	100°C
90.00% (Crude cottonseed oil)	1:5 upto 70°C 1:2 after 70°C	1.350	2.050	3.020	5.220	7.500	10.50	...
95.00% (Refined cottonseed oil)	1:5 upto 60°C 1:2 upto 100°C 1:1 at 100°C	2.969	4.137	5.535	8.221	12.240	20.82	C.M.
98.00% (Crude cottonseed oil)	1:5 upto 60°C 1:2 after 60°C	10.500	16.200	29.550	C.M.	..	...	...
99.94% (Refined cottonseed oil)	1:2 upto 60°C 1:2 after 60°C 1:1 at 70°C	9.124	13.510	21.880	C.M.	...	...	...

(C.M.=Completely miscible)

(*Fig. 1*) SATURATION SOLUTION OF COTTONSEED OIL IN AQUEOUS ETHANOLS AT VARIOUS TEMPERATURES



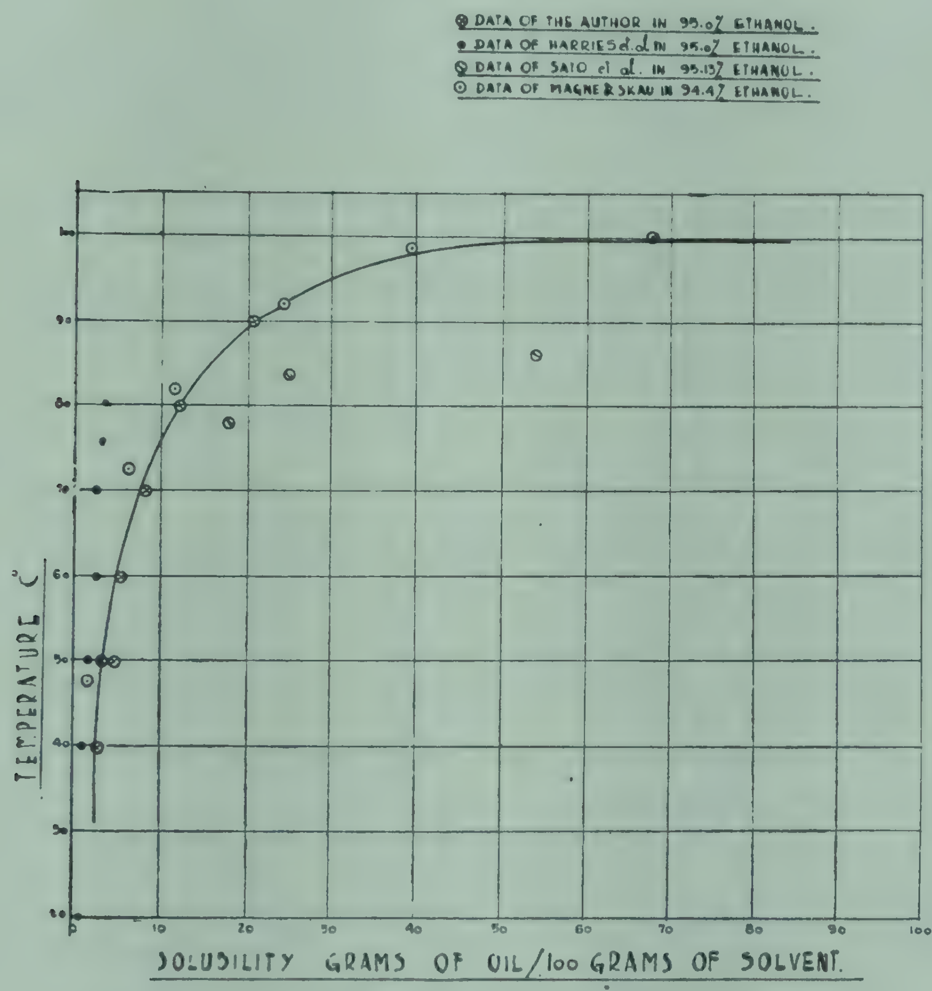
(*Fig. 2*) SATURATION SOLUBILITIES OF COTTONSEED OIL AT VARIOUS CONCENTRATIONS OF ALCOHOL



in the crude oil. Perhaps for a similar reason the miscibility temperatures for crude cottonseed oil in 98% ethanol and refined cottonseed oil in 99.94% ethanol appear to be the same.

In order to compare the results with other data available, the results of Sato *et al.*[1] Harris *et al.*[2] and Magne *et al.*[3] for solubility of cottonseed oil in 95% alcohol are compared in Fig. 3. The results of Sato *et al.*[1] are based on the seal-tube method, which by the nature of the method itself should be expected to give lower results than the present method. However, the results as reported are higher, perhaps because the authors have used crude cottonseed oil. The results of Harris *et al.*[2] are based on the cloud-point method and by the nature of the method, the results are expected to be lower. An improved seal-tube method was used by Magne *et al.*[3] who used a glass bead in the seal-tube to effect better mixing. The results are higher than those of Harris *et al.*[2] but lower than those of the present work, which is expected in view of better mixing in the apparatus used for the present investigation.

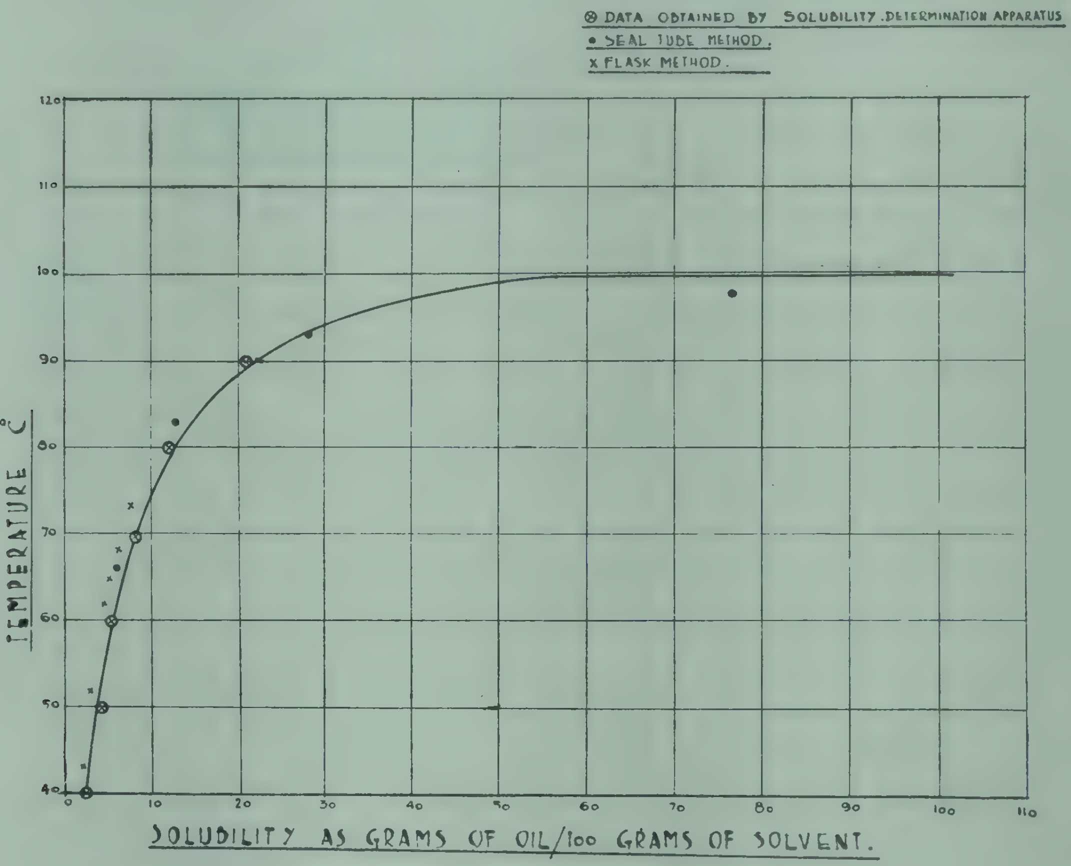
(*Fig. 3*) SOLUBILITIES OF COTTONSEED OIL AS REPORTED BY VARIOUS WORKERS



From the above it appears that the disparity of results may be due either to the method employed or to the quality of oil used. If the results obtained by various methods are to be compared, it is necessary to use the same oil and determine the solubility by each method.

Refined cottonseed oil having the characteristics shown in Table I was used for determining the solubility data in 95% alcohol using the seal-tube method described by Sato and Sakai[6], and the three-necked flask method used by Arnold *et al.*[7] The results are shown in Fig. 4.

(*Fig. 4*) SOLUBILITIES OF COTTONSEED OIL BY DIFFERENT METHODS



The results obtained by the seal-tube method and the three-necked flask method are lower than those obtained by the solubility-determination apparatus. This is to be expected, since in the solubility-determination apparatus there is a thorough mixing of the oil. There is always an excess of oil in the system resulting in two distinct layers, the bottom oil phase and the top alcohol phase. In the present method, the top alcohol phase is sampled and analysed. This method avoids the visual observation of turbid and clearing points. Thus the method used has distinct advantages over those employed previously and the results are likely to be the most reliable so far obtained.

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DISCUSSIONS

Discussion leader: Shri H. V. PAREKH,
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H. V. Parekh. I would like to point out that the number of papers presented do not reflect the importance of the subject.

Alcohol is considered to be a good solvent for the extraction of cottonseed oil, as it is an indigenous material. At one time it was thought that there is a good future for alcohol as solvent in India, but due to the discovery of mineral oil in various parts of the country, it remains to be seen whether alcohol will be used for the solvent-extraction industry or not.

The position of the solvent-extraction industry has completely altered during the last few years. When the first solvent-extraction plant was started twelve years ago, many people were sceptical about its success and were doubtful about the use of deoiled cake for cattle-feed, but today the position is entirely different. A number of solvent-extraction plants have been put up and people have even come round to thinking that solvent-extracted meal would be suitable for human consumption.

Cottonseed is looked upon by different people in different ways in India. A farmer considers it as a cattlefeed, and does not consider expeller cake or solvent-extracted cake as suitable for feeding his cattle. He is ignorant of the assimilation of protein by the cattle, and does not want the oil content to be reduced or the protein content upgraded. In the London market, cottonseed cake sells at a lower price than groundnut cake and is merely dependent on the market price and not on protein quality.

The oilseed crusher wants to get most of the oil from the seed and does not worry about the protein. However, in solvent-extraction of cottonseed cake, considering the quantity of the materials obtained, the deoiled cake forms the main bulk and the extracted oil forms only a by-product.

Government thinks that it has found a hidden treasure of edible oil in cottonseed which can be exploited with no trouble whatsoever!

An oil technologist, however, feels that cottonseed is like a box with a number of organic materials in it.

The two papers are open to discussion.

J. S. Aggarwal. Filtration-extraction-type of process has been developed by the Southern Regional Research Laboratory in the U.S.A. and the patent for commercial exploitation is held by Wurster and Sanger. Has this process been applied in India anywhere and what are its advantages over the other plants available?

C. R. Das. If *desi* seed containing about 5% linters is delinted, the recovery of linters is only about 2-3% and it may not be economical. Will it be possible to crush the low-lintered variety of seed without delinting, and solvent-extract it directly? If it is not possible, what are the difficulties?

K. S. Murti. The published results of the work done at the Oil Technological Institute, Anantapur, were obtained in a laboratory extractor fabricated at the Institute and the rate of extraction was studied using four solvents Pegasol, hexane, S.B.P. spirit and absolute alcohol. The gossypol content of the oil extracted was determined and the oil in each case was refined and bleached. Commercial hexane was found to be the best solvent.

At 82°F the results with various solvents are as follows:

Solvents	*I.V.*	*Gossypol % in oil*
Pegasol	100.2	0.0724
Hexane	104.1	0.0916
S.B.P. Spirit	105.5	0.1093
Absolute alcohol	105.8	0·3189

The rate of extraction with absolute alcohol is very low as the solubility at normal temperature is low. The gossypol content in alcohol-extracted oil is very high. The gossypol content of the meal is in reciprocal order. The colours of the refined oil and the bleached oil are practically the same in all cases.

What are the relative merits of different solvents in actual use by industry and their performance characteristics?

V. K. Parikh. It is reported that solvent-extracted oil can be used in the paint and varnish industry. Can linseed be solvent-extracted satisfactorily?

M. Narayana Rao. If the solvent-extracted meal is to be used as cattlefeed, the gossypol content of the solvent-extracted meal is immaterial; but if used for human consumption, it is necessary that the gossypol should be as low as possible. Good-quality solvent-extracted cottonseed cake should be of great importance to India as a source of protein as there is considerable protein malnutrition in the country. The Multi-Purpose Food developed by the Central Food Technological Research Institute uses solvent-extracted groundnut oilcake as the basis, but Dr. King of the U.S.A., stressed the need for developing a good-quality cottonseed cake which can be used for edible purposes. Such cottonseed cake can be incorporated in foods like Multi-Purpose Food.

The CFTRI, has done work on the solvent extraction of cottonseed oil using absolute alcohol as deoiled cake has been observed to be as low as 0.02%. An additional advantage of using alcohol as the solvent is that when the hot miscella is cooled, it forms two layers, the upper alcohol layer containing most of the gossypol and free fatty acids, and the lower oil layer containing very little gossypol. The F.F.A. of the phase-separated oil is as low as 0.05% and it may not need refining. Even if the cottonseed cake used contains a high proportion of F.F.A. in the oil, solvent-extraction with alcohol yields an oil low in F.F.A. Both oil and cake are of very good quality. Cottonseed cake containing gossypol is toxic to swine, pigs and poultry; in alcohol-extracted cake, the gossypol content is reduced to below 0.03%, thus making the cake suitable for feeding even pigs and poultry.

Is there any method of determining the residual solvent in the cake?

J. S. Aggarwal. There are two aspects which have to be considered if alcohol is used as solvent. Firstly, in view of the low solubility of oil in alcohol at normal temperatures, the extraction has to be carried out at a high temperature. Secondly, the alcohol gets diluted due to the solubility of meal moisture in alcohol. These two aspects are very important if alcohol is to be used in the solvent-extraction industry. Admittedly the quality of cake and oil are better when alcohol is used as the solvent.

T. V. Subba Rao. Whichever solvent is used, the cost aspect of the problem is very important. What is the economic advantage of direct extraction of cottonseed meats as against prepressing followed by solvent extraction? The cost of the process should include the wear and tear of the plant and the replacement of parts also. Some thought should be devoted to this aspect of the problem.

S. A. Saletore. There are a number of plants offered by various manufacturers to the Indian industry. What are the good and bad points of each plant in the overall context of solvent extraction and not necessarily with respect to the extraction of cottonseed oil?

K. Viswanathan. It is reported in the text of the first paper that a certain proportion of deoiled cake and delinted seed could be mixed and supplied as cattlefeed. What is the protein and fat content of the resulting mixture and in what form or shape is it to be sold?

V. K. Parikh. What is the colour of the cottonseed cake produced after solvent extraction and will it be marketable? If alcohol is used as the solvent, what are the gossypol contents of cake and oil?

B. S. Kulkarni. One of the recent developments in solvent extraction is the Filtrex process developed by the United States Department of Agriculture at the Southern Regional Research Laboratory. There are a number of other processes developed and plants put in the market, and it is difficult to evaluate readily the quality of the units offered. Many differ only in matters of detail. After studying all the aspects of the various commercial units, the Filtrex process was developed.

Three or four such plants are working in the U.S.A., about the same number in Latin America, probably 2 or 3 in Italy and a few in Iraq. Egypt is also likely to instal a few. The latest plant of this type to go into production is in Santiago in Chile. The Filtrex process is an improvement over the other prevalent processes and considerable literature and information has been published about the process. The patents for the process are held by Wurster and Sanger and even designs for local fabrication are offered on a royalty basis. The main extractor of the process is in the form of a rotating vacuum filter working in conjunction with a highly-efficient meats-preparation and solvent-recovery system. The process has many advantages over the normal solvent-extraction plants in solvent-recovery and cake-desolventising. Solvent not only falls by gravity, but is also sucked through the cake. The main advantages of the process are:

(a) No meticulous meat preparation is required; only crisping of the meats is necessary, whereas in the other plants, elaborate preparation of meats is necessary to avoid fines.

(b) Solvent utilisation is efficient. The total residence time of solvent is claimed to be about 15-25 minutes compared to 50-60 minutes in other processes.

(c) The concentration of miscella in the Filtrex process is about 25-30% and can even go as high as 32% compared to 18-20% in other processes. This naturally results in saving of steam during desolventising.

(d) The solvent-meat ratio in the process is only 0.8 : 1 compared to 1.8 : 1 of the other processes. This results in the saving of investment on solvent.

(e) The unoccupied volume in the other processes is 2-6 times that in the Filtrex process, which makes the plant very compact, thus saving in the material and building costs.

(f) The solvent content of wet meal as it emerges from the usual extraction plants is about 25-30%, but in the Filtrex process, this is only 20-25% on account of the vacuum used in the process. This also results in the saving of steam during desolventising of meal.

(g) The temperature of solvent extraction is low.

(h) The usual solvent loss in the process is about 0.3-0.4% on the weight of the cake processed, compared to 0.6% in other processes.

(i) No fines are experienced in the miscella, as the repeated filtration incorporated in the process gives a miscella which does not require further filtration.

C. R. Das. The Filtrex plant working in U.S.A. has not been tried for direct extraction but only for pre-press cake. For direct extraction the solvent/seed ratio should be high. Though a low steam consumption has just been claimed for the process, the steam consumption in quotations given by Wurster and Sanger is higher than for the Rotocel process.

R. K. Bhatnagar. Usually Indian industrialists who want to start a new industry prefer to purchase the entire plant and the technical know-how from abroad, sometimes even after paying an unreasonably high price and the heavy royalties attached; they never even consider seriously the salient features and the advantages that a locally-developed process may be offering. This is not only true for the oil-extraction industry, but applies equally to all industries. Ethanol extraction of oil has certain definite advantages. The cake obtained by this process is not only better in quality but can also be formulated to produce protein-rich meals suitable for human consumption. Secondly, the oil obtained is far superior in quality, not only in colour but in that it also does not call for caustic refining. Thirdly, the free fatty acids can be easily recovered from alcohol for the manufacture of quality soap. The only drawback, if at all it can be so called, is the relatively high pressure that is necessary for the operation of the process. With all the recent advances in chemical engineering and plant design, I wonder whether we should be afraid to give the process the real trial that it deserves.

H. J. Talsania. The economics of solvent extraction is very important. The encouragement given to the export of deoiled cake has resulted in more and more solvent-extraction plants being installed in the country and it is essential to go into the costing of these in India.

So far most solvent-extraction plants have been based on groundndut oilcake and not on others. If cottonseed is not used, attempts should be made to understand why the solvent extraction of cottonseed is lagging behind. Due to the high margin of profit in treating groundnut cake, no attempt is made to use cottonseed. Various incentives are necessary to encourage the use of cottonseed.

The price factor should not be ignored while considering the solvent-extraction industry and the prices in the international market have a considerable bearing on the Indian economy also.

N. G. Chatterji. In the present export conditions, almost all solvent-extraction plants work on groundnut cake, as it is very remunerative. Some time back, mahua cake was used in the Tata Oil Mills, Bombay. Linseed cake, mustard cake, etc. were tried to see if there are any difficulties in their solvent extraction, but none was found. Solvent-extraction can also be used for cashewnut-shell liquid and there is one plant working for the purpose outside India. Rice bran oil is extracted by solvent extraction. Thus no difficulties are encountered with any of the common materials.

Cottonseed is not solvent-extracted in India as there are no incentives. There are certain difficulties in the process, but they can be easily overcome. Gossypol is given too much importance. The percentage of gossypol is very low and is not found to be toxic to cattle. Besides, during conditioning of the cake, the gossypol gets bound in the protein.

Certain difficulties in operating the solvent extraction of cottonseed cake are very important and should be carefully looked into. Fine fuzz contained in the cottonseed cake creates some trouble in the operation of the plant by sticking along the pipes and gradually choking them. The problem can be overcome by carefully operating the plant. Suppliers of solvent-extraction plants did not realise the problem in the beginning, but certain improvements have been made in the plant to overcome this. Every solvent-extraction plant made by a reputable manufacturer is good, and can be operated well. Slight differences in the operation details can always be adjusted by the user of the plant, or modifications introduced.

Solvent loss is common to all plants and can be minimised by taking certain precautions. No traces of solvent are found in the deoiled cake and in fact solvent-extracted white groundnut kernels can be used as human food. Steaming and vacuum application removes solvent completely from the cake.

Alcohol as a solvent was tried by me for castor cake some twenty years ago. Since castor oil is soluble in alcohol, it is a good solvent. But apart from the disadvantages already mentioned about alcohol, the main drawback is the excise difficulty, which does not allow the use of alcohol without the use of a denaturant which extracts waxes and other colouring materials from the cake. Besides, the alcohol should be rectified continuously owing to its dilution in the process and the rectified alcohol must contain denaturant in the same proportion as that prescribed by the Excise Department.

H. V. Parekh. Solubility studies of crude cottonseed oil would be more useful than those on refined oil. Alcohol has some advantages over other solvents. Deoiled cake which has been extracted with alcohol can be used safely for human consumption. However, it has certain disadvantages which militate against its use:

1. So far, no commercial continuous plants have been designed. The trend in solvent-extraction is towards continuous plants only and batch plants are obsolete and uneconomical.
2. Solubility of oil is satisfactory in alcohol only at high temperature, and the resultant pressure necessary during the extraction is high, which makes it difficult to design continuous plants.
3. Since the extraction temperatures are about 102°C the protein is denatured.
4. Since alcohol extracts vitamin B also from the meal, the resulting deoiled cake is a poor cattle-feed.
5. Alcohol has no particular advantage over petroleum solvents as alcohol vapours also form an explosive mixture with air.
6. If rectification of alcohol is to be avoided, the cake to be solvent-extracted should be dried to less than 3% moisture content, as otherwise the alcohol gets diluted.
7. An important point to consider is that the price of alcohol is high, and will not compete with that of petroleum solvents.

In spite of the above disadvantages of alcohol as solvent, a 10-ton/day plant for extraction of rice bran oil will be put up shortly in India.

H. V. Parekh (replying)

1. Filtrex seems to be a unique process, but in India no one has had any experience of the practical difficulties in its operation. On the basis of quotations and guarantee figures obtained, it seems similar to other plants.

2. A number of solvents were used in the solvent-extraction plant at Vartej in Bhavnagar. The solvent used at present is not Pegasol but its equivalent ,S.B.P. Spirit 55/115. The latter solvent is very good on a semi-continuous plant and the solvent-extracted oil can be refined to Grade I quality oil if fresh oilcake is processed. *n*-Hexane is the best solvent compared to the others and the Burmah-Shell equivalent is equally good.

3. As regards the statement that cottonseed oil could be used in the paint and varnish industry, the glycerides can be separated into saturated and unsaturated fractions by solvent extraction with propane under high pressure and the unsaturated glycerides can be used in the paints and varnish industry.

4. Gossypol in the deoiled cottonseed meal should not be a problem when the latter is used as cattlefield; however, the gossypol in the oil should be removed by refining.

5. It is suggested that deoiled cake be mixed with a certain proportion of cottonseed, so that the resulting mixture could contain about 3-4% of oil for use as cattlefeed.

6. As regards Government policies, it is agreed that a liberal policy is necessary as regards the solvent extraction of cottonseed oil. The solvent extraction of groundnut is a well-established industry at the moment, but the prospect for cottonseed is not very bright. With a liberal policy on the part of Government, the solvent extraction of cottonseed could be established on sound lines.

7. Compulsion of solvent extraction of cottonseed is not possible as most of the present solvent-extraction plants are not located in the cottonseed areas. In the solvent-extraction plants, it may not be economical to use cottonseed at all.

8. If alcohol is used as the solvent, the cake and the oil are of better quality and could be used for edible purposes without hesitation.

T. V. Subba Rao. If alcohol has all the disadvantages mentioned, why was the 10-ton plant for the extraction of rice bran based on alcohol as the solvent sanctioned? If some industries are based on alcohol as the solvent, will there be enough alcohol to cater to the requirements of the industry? If the plant based on alcohol as the solvent is to be switched on to the conventional solvents, what changes are necessary for working the plant?

H. V. Parekh. As far as the supply of alcohol is concerned, there is ample production now and there are few outlets at the moment for the solvent. Government is offering some concessions so that it is used in various industries.

The solvent-extraction plant for rice bran based on alcohol as the solvent is only a research pilot-plant unit at the Central Food Technological Research Institute at Mysore, for study of working data and the economics of the process.

J. G. Kane (communicated).

1. The suggestion is made in Paper 1 (under 'Conclusion', item 3) that "a mixture of deoiled meal and whole cottonseed......should be considered good cattlefeed in India." I would rather suggest the blending of cottonseed oil cake and the deoiled meal. This would encourage both solvent extraction as well as crushing of the seed.

2. It is stated in Paper 1 that cottonseed oil may be used by the paint and varnish industry of India. It will be agreed that this is a somewhat academic idea. With linseed oil, D.C.O., safflower oil, nigerseed oil and now tobaccoseed oil available in this country, no necessity may ever arise of consuming cottonseed oil in the paint industry.

3. Along with the information on solubility of cottonseed oil in ethyl alcohol given in Paper 2, data on the solubility of the latter in the oil are equally important. We have found that significant quantities of alcohol (1 to 5%) are dissolved by groundnut oil at room temperature, the controlling factors being temperature, concentration of alcohol and per cent F.F.A. of the oil (Cama, Domadia and Kane, J. Oil Tech. Association of India, 1953, *9*, 50). The alcohol-extracted oil will have to be freed from the dissolved alcohol and this will have to be taken into account in considering the economics of solvent extraction by alcohol.

SECTION IV

REFINING OF COTTONSEED OIL

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1. REFINING OF COTTONSEED OIL—A REVIEW

By

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The impurities present in cottonseed oil, effect of mode of production on the impurities present and methods of refining of the oil have been reviewed.

Introduction

Raw oils and fats by whatever method produced contain variable amounts of non-glyceride impurities. Cottonseed oil, unlike other vegetable oils, is very dark in colour and contains so much of these impurities that it is practically unusable in the raw state. Jamieson and Baughman[1] have reported the following impurities in raw oil: raffinose, pentosans, resins, proteoses, peptones, phosphatides, phytosterols, phytosteroline, inosite phosphates, xanthophyll, chlorophyll, free fatty acids and mucilaginous substances. However, all the impurities of the raw oil are not undesirable.

Coloured Impurities in Raw Cottonseed Oil

The colour of raw cottonseed oil is to a large extent due to pigments of the gossypol type and their oxidation or polymerisation products. The complexity of the structure of gossypol is manifested in the large variety of its reactions. It acts as a strong dibasic acid and is readily soluble in dilute aqueous NaOH, KOH and Na_2CO_3 solutions. It also reacts with organic bases, such as aniline and pyridine. With aliphatic acids it forms compounds containing one molecule of acid for one molecule of gossypol. In its capacity as polyphenol gossypol readily forms stable esters and ethers. Gossypol has been shown by Royce[8] to have strong antioxidant properties. Alkali-refining removes a good deal of the colouring matter present in the raw oil. The colour of the refined oil is largely related to the amount of gossypol present in the raw oil which varies with the method of production of the oil. Podol'skaia and Tobler[2] have shown that with increasing gossypol concentration the colour of the oil is greatly intensified. Besides gossypol, other pigments related to it, *viz.*, gossypurpurin, gossycaerulin, gossyfulvin are associated with the raw oil, which are products from gossypol converted during cooking of the seed.[3] Gossycaerulin is mostly found in cooked cottonseed only. The other pigments reported to be present in the seed and the oil are anthocyanins, carotenoids, chlorophyll, resin pigments, etc. The dark colour of crude cottonseed oil has often been attributed to the presence of resin pigments.[4] The oil-soluble carotenoids pigment reported by Podol'skaia[4,5] was found to be in greater extent in immature than in mature seed, but it was present in all expressed and solvent-extracted cottonseed oils examined. Cottonseed pigments undergo constant alteration during storage of the seed. Seed stored at a high moisture content or at a high temperature develop dark colours in the oil.[6] Very little of the chlorophyll of crude oil is removed during alkali refining, but it appears to be completely removed during subsequent bleaching of the oil.

The mode of production of the oil has a great effect on its colour. The different methods of production are expression in hydraulic presses, expression in oil expellers, expression by the Skipin process and solvent extraction.

In India the seed is crushed either in hydraulic presses or in expellers, both of which involve preliminary heating or tempering of the seed. Since higher pressures are employed in expellers, the seed is usually not subjected to so much cooking as in hydraulic presses. By proper control of moisture content, temperature and time of cooking, it is possible to produce oils of light colour with low refining losses. Prolonged cooking at high temperatures causes excessive fixation of colour in both oil and meal. Addition of moisture after preliminary heating of the seed has been reported[7] to lower the colour of the expressed oil. Royce and co-worker[8,9] have reported that the gossypol content of raw hydraulic-pressed oils ranges from 0.039-0.21%. Thornton[10] has stated that cooking of cottonseed was necessary to dehydrate the resin contents of the glands and thereby prevent them from dissolving in the expressed oil.

The Skipin process has not been practised in India so far. The advantages of the Skipin process as reported are: (i) higher oil recovery, (ii) oil of good quality which refines easily, (iii) free gossypol removal with the oil, the press cake containing practically no free gossypol.

In solvent extraction, the choice of a suitable solvent is of prime importance to get an oil of good colour. Extraction with alcohol has been reported to be better than with petroleum naphtha, benzene, etc., as it gives an oil of lighter colour when hot extraction is done at 78°C with 85% (by weight) alcohol.[11] Impurities such as colouring matter, gossypol and fatty acids are carried away with the solvent, leaving a comparatively pure oil.

The extracted meal is low in gossypol content unlike the hexane-extracted meal which has a high content (1.2%) of gossypol.[12] The oil obtained is low in gossypol, fit for edible purposes and easy to hydrogenate. It has low free fatty acid content (0.3-0.4%) and a light colour (24 Y and 3.5 R) which by simple caustic refining can be reduced to 10.1 Y and 1.0 R.[12]

Refining of the Oil

Cottonseed oil is usually refined by alkali neutralisation. In recent years, solvent refining has been introduced in the U.S.A., but it is doubtful if this will be able to compete with the newer continuous alkali-refining process.

The alkali generally employed is caustic soda, which is much more effective in its decolourising action than weaker alkalies. The alkali combines with the free fatty acids to form soap, extracts the colouring matter by a selective solvent action, coagulates or destroys lipids and other minor constituents and removes suspended foreign matter. The soap and other materials rendered insoluble (known as soapstock or foots) are then removed by gravity settling or otherwise.

The presence of phosphatides, proteins, etc., generally tend to increase refining losses. By increasing the amount and strength of alkali used, an oil of improved colour is obtained but at the same time the refining losses are increased. In the first stage of refining intimate contact between the lye solution and the oil is brought about by stirring. As heat is important in increasing the speed of reaction, an optimum temperature is necessary. A lye of suitable strength is chosen, which should be added in such excess that after neutralisation of all the free fatty acids and other reactive substances, the remaining lye is sufficiently strong to effect a good break without the addition of salt. Om Prakash *et al.*[13] found that the optimum amount of excess alkali with oils of acid values from 7-9 is 25% and for oils with acid values 10-14 is 20%. They have also suggested a procedure for eliminating most of the colouring matter and other impurities from soapstock for use in the manufacture of washing soap.

Batch System of Alkali Refining

The older method of alkali refining is of the batch-type, in which the equipment consists of a cylindrical tank with a conical base equipped with a mechanical stirrer with variable speed from 8-35 R.P.M., and fitted with a steam coil or steam jacket.

In the batch system, both "dry" refining and "wet" refining can be carried out. In dry refining relatively strong lye is used and soapstock is recovered in a more or less solid form, whereas in wet refining weaker lye is used and soapstock is recovered in more or less fluid form. Dry refining has the advantage of being rapid and convenient and produces a concentrated soapstock, and is particularly adapted to the refining of cottonseed oil.

After the kettle is charged with the oil, the agitator is started at a medium speed and the temperature is adjusted to 75-80°F. Then lye of suitable strength (10-15°Bé) is sprayed through a series of nozzle-type spreaders. Speed of agitation is increased and continued for 15-20 minutes to permit the greatest possible dispersion of lye in the oil. The temperature is then slowly raised (approximately 2°F per minute) to 125-135°F. Under the influence of heat, the emulsion breaks and soapstock separates. During the "break" the agitation should be slowed down. After the desired degree of "break" is obtained, the agitation is stopped and the mass is allowed to stand from 8-14 hours. Then the refined oil is drawn off from the top, by means of a swivel joint pipe. The oil is then filtered after treating it with a small amount of bleaching earth and pumped to a storage tank. In the wet method the oil is washed with hot water and then dried under vacuum.

The batch system refining suffers from the following defects: (i) a long time of contact between the oil and alkali, resulting in saponification of neutral oil, (ii) inefficient separation of neutral oil from the soapstock (generally soap entrains upto 1.5 times its own weight of oil), (iii) loss of neutral oil during washings in the form of emulsion.

The loss of neutral oil in the soapstock can be minimised by the use of centrifugal separators and the loss due to washing can be minimised by passing the wash waters through baffled settling tanks and recovering as much of the floating oil as possible.

There are several patents specifying use of chemicals for achieving efficiency in alkali refining process such as Clayton's patent[14] relating to the use of lower aliphatic alcohol or esters during neutralisation and the Edward Leibscher[15] process which consists in adding glycerol or other polyhydric alcohols to the lye, and Lange's[16] patent requiring addition of solid salicylic acid (about 0.01%) to the raw oil.

Re–refining

Sometimes refining in stages is employed with very dark-coloured oils. Off-grade cottonseed oils are usually refined first with a strong lye containing about 0.6-0.8% excess

NaOH, and later re-refined with a smaller percentage of weak lye. Kronen and Feuge[17] got the greatest amount of colour removal by using very small amount of alkali solution (0.2% NaOH) in the re-refining process. Bhasin and Aggarwal[18] by introducing certain modifications and increasing the speed of stirrer (about 1,200 R.P.M.) have got a re-refined oil of acid value 0.43 and colour 19 Y and 3.3 R.

Continuous System of Alkali Refining

The latest method of alkali refining is the continuous method. It reduces the time of contact between caustic and oil and effects a very efficient separation of foots and oil. Also, it allows the use of weaker alkalies like Na_2CO_3 which do not attack the neutral oil.

The oil and the lye in required proportions are discharged in mixers consisting of small horizontal chambers equipped with fast-revolving paddle blades, whence the emulsion is passed through a heat exchanger in which it gets heated to about 140°F. The oil, containing agglomerated particles of soapstock, then flows to continuous centrifugal separators where the oil is discharged as a light effluent and the soapstock as a heavy effluent; the total time of contact between the oil and the caustic lye is approximately 2 minutes. The oil is then given a washing treatment with about 10% of its own weight of hot water, the temperature being kept at 160°F. The oil and water in required proportion are passed through a mixer and then through a secondary battery of centrifugal separators. The yield of neutral oil is higher in this case than in the batch process.

A successful refining operation should give a maximum yield of refined oil containing not more than traces of free fatty acids and free from the major part of the colouring matter and other non-fatty matter.

Refining Loss

The following approximate relationship between free-fatty acid content of cottonseed oil and refining loss has been suggested by Royce and Kibler:[9]

% refining loss=4.25+2.3×F.F.A.%. The presence of much gossypol in crude oil leads to the production of a firm soapstock and low refining loss.[19] Impurities of phosphatidic and proteinaceous nature contribute to a high refining loss.

Colour of Refined Oil

The colour of refined cottonseed oil depends more or less on the free fatty acid content of the raw oil since deterioration changes in the seed lead alike to hydrolysis in the oil and production of oil-soluble pigments. The following equation has been suggested to represent the relationship between the colour of refined oil and F.F.A. content of the raw oil.[20]

Colour of refined oil (in Lovibond red units)=4.0+1.1×F.F.A. % of raw oil.

Neutral Oil Content

The following equation devised by Wesson[21] and modified by Jamieson[22] indicates approximately the relationship between the content of neutral oil, F.F.A.% and phosphatides and other impurities reactive with alkali present in the raw oil.

$$N=100-(F+I)$$

Where N = % of neutral oil, F = % of free fatty acids and I = % of reactive impurities, the value of I varying from about 0.6 to 2.4%: The difference between 100 per cent and the per cent of neutral oil present is often referred to as the Wesson loss. It is of significance in refining theory and practice, inasmuch as it represents a minimum value beyond which the refining loss of oil cannot be reduced.

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2. SOME LABORATORY STUDIES IN REFINING COTTONSEED OIL

By
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Various aspects of refining cottonseed oil in the laboratory are reported. With fresh oils, increasing the lye strength and excess has little effect on refining loss but improves colour; with old and colour-fixed oils, use of excess or strong lye increases refining loss considerably without greatly improving colour. Storage of crude oil results in strong colour fixation. Refining at low temperature, or cooling a hot oil as it emerged from the expeller, were of no advantage. Double refining yields light-coloured oils. The use of 2-10% alcohol in the refining lye yielded extremely light-coloured refined and bleached oils. The graphs connecting F.F.A. of crude oil with refining loss, and refined and bleached oil colours, show that at about 9-10% F.F.A., a refined oil will tend to be almost unbleachable.

Introduction

Cottonseed is perhaps the one *cultivated* oilseed of India not developed as a source of oil over the centuries for at least one obvious reason: unlike every other traditional edible oil, it is not edible or inviting, and probably poisonous, as obtained in the crude state by expression. The establishment of suitable refining techniques since the turn of the century, especially in America, has stimulated world-wide interest in developing cottonseed as an edible oil source in preference to its traditional use as cattle fodder.

While much can be gained from the American example, some circumstances are peculiar to this country. First, it has been known and is now well-documented from the Indian work at this Laboratory that the long intervals between harvesting and ginning and milling; especially in humid weather, can lead to a fixation of colour in the oil; this will be shown by a darker colour in the refined oil derived from stored seed and much darker colour in the bleached oil, *i.e.*, more pigments are left in the oil after refining and they are also more resistant to bleaching. Hence the refining of Indian cottonseed oils colour-fixed by seed storage to really light-coloured products is a major problem in any study of this kind, and is an aspect not intensively studied in America where the problem, when it tends to arise in practice, is overcome by controlled seed storage. Storage of crude oil itself is also reported in the present study.

Secondly, cottonseed oil refining necessitates use of a strong alkali if pigments are to be removed, and this leads to a hard soapstock. Indian oil millers have so far used dilute lyes for refining other vegetable oils, and the refining kettles have been designed to run off the resulting liquid soapstocks. Hence, one aspect studied in this work was to refine the oil with strong lye, and then wash with 10% water to give a softer soapstock and also wash the oil free of soap. This has been called the "wet soap" method to avoid confusion with the wet method where dilute lye is used. Against this present practice, the growth anticipated in the utilisation of soapstock or foots for acidulation and fatty acid distillation would lead to a demand for harder and less bulky soapstocks, and thus to a preferential trend towards dry refining.

Various aspects of the studies now reported are connected with colour fixation. The use of various additives during the refining procedure, some designed to bind the gossypol more firmly in the soapstock and others to reduce the refining loss, has been tried. Re-refining of once-refined oils has been looked into. The effect of long storage of oil itself has been studied, and the colour fixation believed to occur immediately after expelling examined. Refining at various temperatures has been studied, on the basis of the report that low-temperature refining gives light-coloured oils.

This interim progress report has shown certain trends; further work to follow this up, which is in progress, will be reported later in full.

Results and Discussion

Experimental and analytical techniques:—The A.O.C.S. Method No. Ca 9a-41 for refining loss (RL) was closely followed except for such variations as are specifically mentioned. Bleaching was also done by the A.O.C.S., Method No. Cc 8a-46 using 6% of Tonsil Optimum earth. A battery of four refinings and of four bleachings could be run on the units available. Colour readings of refined and bleached oils using Lovibond yellow and red graded glasses were usually made on a 1-inch cell, and occasionally, in earlier studies, on a 0.25-inch cell. These colours are reported in the tables as ROC-1, BOC-1 or ROC-¼, BOC-¼.

GENERAL ABBREVIATIONS USED IN THE TABLES

F.F.A.	...	Free fatty acids of oil as % oleic.
AOCS max.	...	Maximum weight of lye for the particular F.F.A. as read from AOCS tables forming part of refining method Ca 9a-41.
RL	...	Refining loss %
ROC—1/4	...	Refined oil colour on Lovibond 1/4– inch cell.
ROC—1	...	Refined oil colour on Lovibond 1–inch cell.
BOC	...	Bleached oil colour as above
Order of colour readings	...	Y, R, Y + 10R.
P.O.V.	...	Peroxide value

TABLE I

Repeatability of Refining Method

Lye used:– 20° Bé, AOCS Max.

F.F.A.	No. of trials	RL	ROC–1/4		
			Y	R	Y + 10 R
		(a) Dry Method.			
1.36	3	5.6—6.0	14	1.6 (Identical)	30
1.73	2	7.5—8.0	12.5	1.2 (Identical)	25
1.18	4	7.6—7.8	10.0	1.0,1.1	20,21
		(b) Wet Method.			
1.20	5	6.0—7.3	12–14	1.5	27–29
1.90	2	8.2–10.8	12.5,14	1.8,2.0	32,33
				ROC–1	
1.36	6	7.8—9.8	23	15.6	179
1.73	7	3.7—4.9	26	5.8	84

TABLE II

Dry and Wet-Soap Refining

F.F.A.	Excess lye over AOCS Max. %	RL		ROC–1/4					
		Dry	Wet–soap	Dry			Wet–stoap		
1.3	200	4.4	3.8	22	1.6	38	18	1.7	35
	300	5.3	4.6	15	1.4	29	17	1.5	32
	400	5.6	5.1	10	1.3	23	14	1.3	27
1.7	100	5.0	3.7	20	3.8	58	21	2.4	45
	200	5.2	5.0	16	2.6	42	20	1.8	38
	300	6.6	6.1	14	2.2	36	20	1.4	34

TABLE III

Effect of Lye Strength and Excess on Refining

F.F.A.	Lye strength and excess		RL	ROC–1/4			BOC–1/4		
	°Bé	% of max.							
1.26	16	80	7.0	10.5	1.5	26	4.0	0.7	11.0
	20	80	5.8	9.0	1.0	19		—	
	20	Max.	6.8	8.0	1.1	19	2.6	0.5	7.6
2.0	16	80	6.4	10.5	1.0	21	1.5	0.4	5.5
	20	80	6.2	10.0	1.5	25	1.7	0.4	5.7
	20	Max.	6.7	8.8	1.0	19	1.5	0.4	5.5
2.1	16	80	5.6	9.3	1.0	19	2.3	4.0	6.3
	20	80	7.3	9.0	0.9	18	2.4	0.3	5.4
	20	Max.	6.3	7.0	1.0	17	1.3	0.4	5.3
2.45	20	Max.	10.0	11.0	1.6	27		—	
	24	Max.	11.0	11.5	1.5	25		—	
	26	Max.	12.4	11.0	1.5	26		—	
1.30	20	200	4.9	28.0	3.8	66		—	
(Stored 6 months)	20	300	—		—			—	
	20	350	7.5	26.0	3.3	59		—	
	20	450	9.5	20.0	3.0	53		—	

TABLE IV

Long Storage of Crude Oil

Oil sample	Period of storage	F.F.A.	R.L.	ROC—¼			BOC—¼		
				(a) Various samples on long storage					
A	As recd.	1.3	5.7	10	1.2	22		—	
	6 months	1.3	7.0	20	2.3	43		—	
B	As recd.	1.3	5.4	12	1.3	25		—	
	6 months	1.3	9.5	26	3.3	59		—	
C	As recd.	3.5	9.3	55	0.6	11		—	
	10 months	3.8	12.0	10	1.8	18		—	
				(b) Samples studied at intervals					
D	As recd.	1.2	7.3	25	3.6	61	2.6	0.4	6.6
	15 days	1.2	7.7	24	3.8	62	3.8	0.7	10.8
	30 days	1.2	7.4	24	4.3	67	5.0	0.8	13.0
	45 days	1.2	8.6	25	4.6	71	5.5	1.0	15.5
	60 days	1.2	7.2	26	5.6	82	8.0	1.0	18.0
	75 days	1.2	7.6	26	5.8	84	8.0	1.2	20.0

TABLE V

Long Storage of Refined and Bleached Oils

S. No.	Sample	Colour — ¼									Increase in 85 days	
		Original			After 42 days			After 85 days			F.F.A.	P.O.V.
1.	Refined oil	10.5	1.0	21	9.5	1.0	20	8.9	1.0	19	0.1-0.2	50-80
2.	,,	8.8	1.0	19	7.8	1.1	19	6.8	1.0	17		
3.	,,	7.0	1.0	17	5.0	0.7	12	4.2	0.5	9		
4.	Bleached oil	1.7	0.4	5.7	1.2	0.2	3.2	1.0	0.2	3.0	0.1	112
5.	,,	2.4	0.3	5.4	1.1	0.2	3.1	1.0	0.2	3.0		
6.	,,	1.3	0.4	5.3	0.8	0.2	2.8	0.8	0.2	2.8		

TABLE VI

Changes in the First Days Following Expelling

(a) Oil of F.F.A. 1.6

Days of storage		0	1	2	4	6	8	12
RL		6.2	7.0	8.4	5.6	5.3	5.7	5.8
ROC—1	Y	16	15	12	12	12	14	14
	R	2.3	2.2	2.2	2.4	2.3	2.5	2.5
	Y+10R	39	37	34	36	35	39	39
BOC—1	Y	2.0	2.0	2.0	2.5	2.0	2.4	2.3
	R	0.3	0.2	0.2	0.3	0.3	0.3	0.4
	Y+10R	5.0	4.0	4.0	5.5	5.0	5.4	5.3

(b) Oil of F. F. A. 1.4

Days of storage		0	2	4	6	7	8	14
RL		6.8	6.3	6.8	6.8	7.0	6.8	7.7
ROC—1	Y	26	24	22	25	24	25	24
	R	3.6	3.2	3.6	5.3	4.2	4.5	3.8
	Y+10R	62	56	58	78	66	70	62
BOC—1	Y	2.8	3.5	3.3	3.7	3.6	3.6	3.8
	R	0.4	0.3	0.5	0.6	0.6	0.6	0.7
	Y+10R	6.8	6.5	8.8	9.7	9.6	9.6	10.8

TABLE VII

Effect of Cooling Hot Oil as Expelled

Temperature of emerging oil 80-85°C; of cooled oil 15°C

Days of storage		1		2		5		8		12	
Oil (cooled or uncooled)		C	U	C	U	C	U	C	U	C	U
RL		5.6	6.2	6.1	7.0	5.5	5.6	5.4	5.7	5.7	5.8
ROC−1	Y	15	16	14	15	12	12	13	14	13	14
	R	2.2	2.3	2.1	2.2	2.4	2.4	2.4	2.5	2.5	2.5
	Y+10R	37	39	35	37	36	36	37	39	38	39
BOC−1	Y										
	R										
	Y+10R	5.0	5.0	4.0	4.0	5.0	5.5	5.0	5.3	6.2	6.3

TABLE VIII

Double Refining of Cottonseed Oil

(*a*) *Sodium hydroxide twice, various samples of refined oil*

Sample		1	2	3
ROC—¼	Y	14	8.8	5.5
	R	2.0	1.0	0.7
	Y+10R	34	19	13
Lye strengh, °Bé.		20	16	16
% lye on oil		4	2	4
RL		2.2	3.3	4.6
Re-ROC—¼	Y	3.5	5.3	2.7
	R	0.6	1.0	0.3
	Y+10R	9.5	15.3	5.7
BOC—¼	Y	1.5	1.2	0.8
	R	0.1	0.1	0.2
	Y+10R	2.5	2.2	2.8

(*b*) *Sodium hydroxide twice, oil F.F.A. 2.7*

		Expt. 1	*Expt. 2*	*Expt. 3*	*Expt. 4*
First lye,	strength, °Bé	12	12	14	14
	quantity	Theoretical	Theoretical	Theoretical	Theoretical
Second lye,	strength, °Bé	20	20	20	20
	% on oil	4	7	4	7
Total RL		11.4	13.2	11.0	12.1
ROC — 1	Y	20	16	16	16
	R	4.4	4.2	4.4	3.6
	Y+10R	64	58	60	52
BOC — 1	Y	6.0	5.5	5.0	5.0
	R	1.6	1.0	1.4	0.9
	Y+10R	22	16	19	14

(*c*) *Sodium carbonate first, then sodium hydroxide, oil F.F.A. 2.7*

First lye,	strength %	10	10	10	10
% excess over theoretical		Theoretical	20	40	60
Second lye,	strength, °Bé	20	20	20	20
% half orginal AOCS max.		5.2	5.2	5.2	5.2
Total RL		10.3	11.4	10.7	10.3
ROC — 1	Y	27	26	23	20
	R	6.6	5.7	5.6	5.5
	Y+10R	93	83	79	75

TABLE IX

Refining at Various Temperatures

(*a*) *Oil of F.F.A. 3. 1, lye 20 °Bé.*

Temp. of refining, °C		10			25	33	40
Lye excess, % max.		80	Max.	120	Max.	Max.	Max.
RL		11.6	12.4	14.6	12.5	12.5	14.7
ROC — 1	Y	27	26	26	26	26	26
	R	7.5	7.0	6.0	6.0	6.0	7.2
	Y+10R	102	96	86	86	86	98

(*b*) *Oil of F.F.A. 2.7, lye 20° Bé, max.*

Temp. of refining, °C		8	10	30	40
RL		11.2	10.3	12.0	11.2
ROC — 1	Y	20	16	28	16
	R	3.0	3.0	3.0	3.2
	Y+10R	50	46	58	48
BOC — 1	Y	6	4	4	6
	R	0.4	0.6	0.6	0.8
	Y+10R	10	10	10	14

TABLE X

Use of Additives

Additive	Method used	Effect on RL and ROC
Common salt	Dry	None
,, ,,	Wet soap	None
Alum	Dry	None
,,	Wet soap	Increased RL
Tartaric acid	Dry	None
,, ,,	Wet soap	Slightly decreased RL Increased colour
Lignins, several forms.	Dry	Slightly decreased RL
,, ,,	Wet soap	Slightly increased RL
Katha	Dry	None

Preliminary clarifications, before refining, with aqueous sulphuric acid, citric and tartaric acids were without effect on subsequent RL and ROC.

TABLE XI

Use of Alcohol with Refining Lye

Oil F.F.A. 1.2

Alcohol added to lye, % oil	R.L.	ROC–1	BOC–1
None	7.1	20 6 5 85	8 1.2 20
2	8.1	16 4.0 56	7 1.0 17
4	9.5	16 4.0 56	6 0.8 14
6	9.3	13 3.9 52	6 0.7 13
8	9.2	14 4.0 54	4 0.5 9
10	8.6	14 4.0 54	4 0.4 8

TABLE XII

Correlations Between Seed Oil F.F.A., Refining Loss, Refined Oil Colour and Bleached Oil Colour

F.F.A. of seed oil	R.L.	ROC–1 (Y+10R)	BOC–1 (Y+10R)
0.5	4.3	47	7
1.0	5.6	50	8
1.5	6.6	56	9
2.0	7.8	62	11
2.5	9.0	69	13
3.0	10.0	75	17
3.5	11.4	83	23
4.0	13.0	90	32
5.0	17.0	105	57
6.0	21.0	120	86
7.0	25.0	160	115

Results

1. *Degree of repeatability*: *Table I*:—It was generally found that the A.O.C.S., dry methods was repeatable to about ± 0.2 units of refining loss, but that the wet soap method, probably owing to the difficulty of adding water and agitating in a controlled way, was only repeatable to ±0.8 units.

2. *Dry and wet soap refining methods*: *Table II*:—Owing to the above difficulty of erratic RL, comparisons between the methods are rather difficult. However, in one series of consistent experiments, it was found that the refining loss by the dry method, at several different lye concentrations, was regularly about 0.5% more than by the "wet soap" method, indicating that the addition of hot-water has released some neutral oil which would otherwise have been entrained in the soap mass. Colour tended perhaps to be slightly lower in the dry-refined oil, perhaps because the released entrained oil is dark.

3. *Effect of lye strength and excess*: *Table III*:—When the oil is of good quality, *i.e.*, fresh, not pigment-fixed and of low acid value, increasing the excess of lye and its strength has little or slight effect on the refining loss, but the colour of refined oil is always improved with the use of more or stronger lye. With high-acid oils, it would appear that the use of increasingly stronger lyes increases the refining loss considerably, with only a slight progressive decrease in the colour.

4. *Long storage of crude oil*: *Table IV*:—Storage of expressed crude oil results in only slight increase of F.F.A., probably owing to the strong antioxidant effect of gossypol present. Yet the RL is slightly but definitely increased by about 3 units in 6-10 months storage. More serious are the effects on colour. The refined oil colour steadily rises (IVb) and appears to double in both red and yellow components in 6-10 months (IVa). The bleached oil colour is affected even more strongly, and in one example studied has increased threefold in 2.5 months (IVb). Colour fixation definitely occurs on long storage of crude oil, with little increase of F.F.A., but slight increase in RL.

5. *Long storage of refined and bleached oils*: *Table V*:—Storage for 85 days in glass beakers led to definite colour loss in refined and bleached oils, probably by the bleaching effect of light. Alongside, acid values did not rise at all and were below 0.2% for all the samples; peroxide values rose by 50-80 units for the refined oils and by 112 units for the bleached oils in the 85 days of storage.

6. *Changes in the first days following expelling*: *Table VI*:—There is a very slight but consistent lowering of refined and bleached oil colour in the first 2 or 3 days after expelling, and the RL is somewhat erratic: we are inclined to attribute this to the settling of fines in the first few days. Thereafter there is a slight but steady increase in both RL and colour, but no sudden change at any point.

7. *Effect of cooling hot oil as expelled*: *Table VII*:—Cottonseed oil as it emerges from the expeller is extremely hot (80-85 °C) and when bulked takes a considerable time to cool down, during which period fixation of colour can conceivably occur. The hot oil was cooled as it emerged using ice-salt to 15 °C, and its storage characteristics over about two weeks compared at intervals with an uncooled sample of oil collected at the same time. Little difference in RL, bleached oil colour or refined oil colour over twelve days storage could be noticed between the cooled and uncooled oils.

8. *Double-refining*: *Table VIII*:—The refined oils in Part (a) of Table VIII have all been greatly reduced in colour by refining, with a further RL of about 2-4%, mainly mechanical and entrainment losses since once-refined oils have an F.F.A. below 0.2%. On further bleaching, really pale-coloured oils are obtained with a Y + 10R colour on a 1-inch cell of only 8-9 units.

The two-stage refining studies reported use of various proportions of sodium hydroxide either twice (b), or following sodium carbonate (c), on the same oil sample. In the former, the RL and colour follow exactly the quantity of lye used, and in practice a choice will have to be made between low refining loss and low colour, and no doubt refining loss would at present be considered the more important. The final double-refined and bleached oils are not of as good a colour as that in Part (a) of the Table, perhaps because the original oil was more colour-fixed in the second case. When sodium carbonate is used for the first refining, followed by sodium hydroxide, the resulting refined oils are very much darker than when hydroxide is used twice, though the RLs are perhaps about 1% lower.

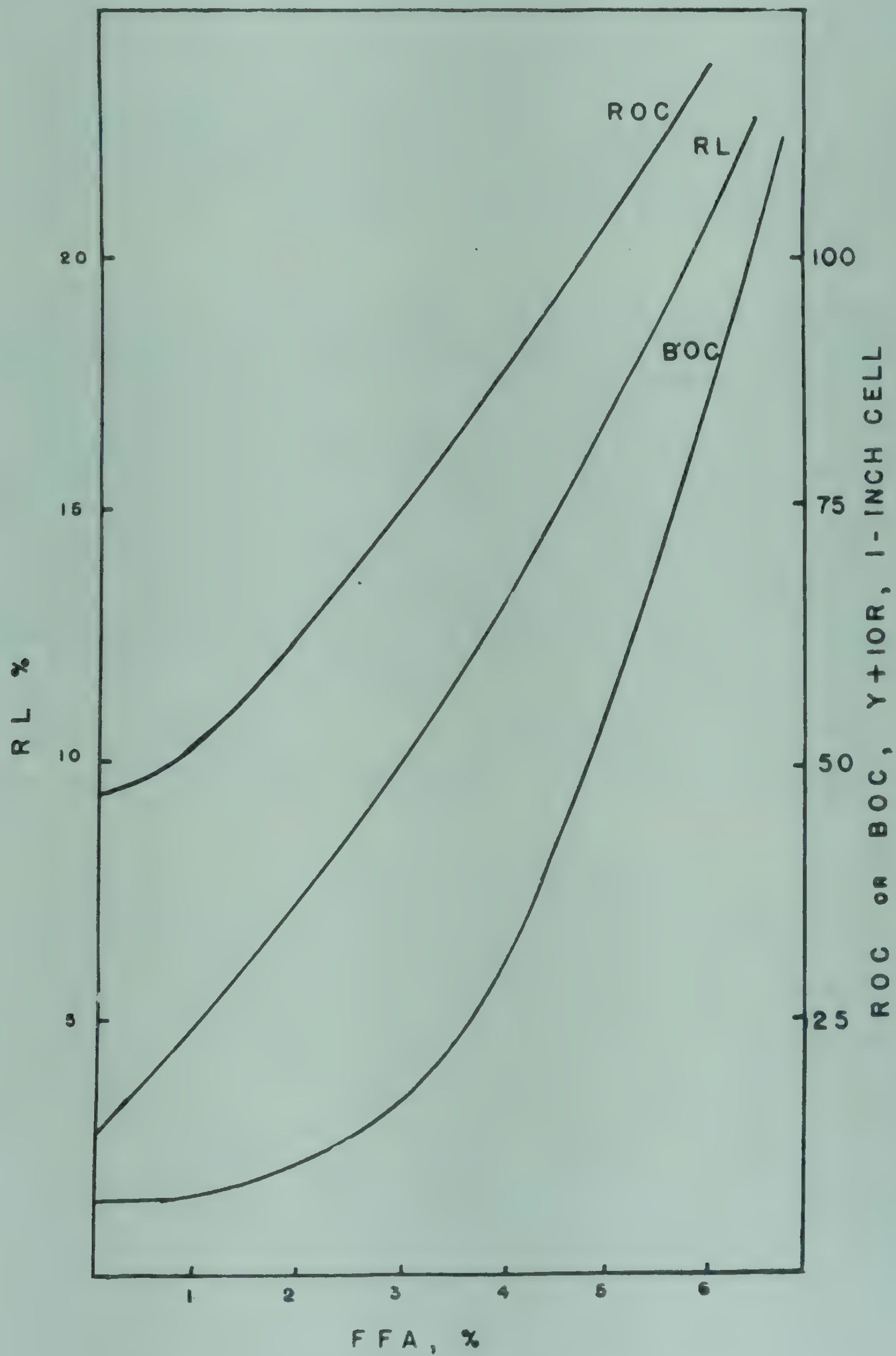

Fig. 1. F.F.A. of oil, and corresponding Refining Loss, Refined oil colour and Bleached oil colour.

9. *Refining at various temperatures*: *Table IX*:—Low-temperature refining is believed to be beneficial during cottonseed oil refining. Experiments in which the refining was conducted at 10, 25, 33 and 40°C did not show any benefit in refining loss or in colour. At 10°C, 3 different lye excesses were tried. The oil was an old one, and again excess lye increased the RL without greatly affecting colour, as observed earlier. A second experiment at 8, 10, 30 and 40°C has confirmed these results.

10. *Use of additives*: *Table X*:—A very large number of additives have been tried by both the dry and wet soap methods, with occasionally a slight beneficial effect on RL or colour. Preliminary clarifications with aqueous sulphuric, citric and tartaric acid were without effect on subsequent RL or colour.

11. *Use of alcohol*: *Table XI*:—When 2-10% of 95% ethanol was added to the refining lye, there was a slight increase of *ca.* 1.5% in RL, but a marked reduction in the colours of refined and particularly of bleached oils. Since the oil was fresh, the method remains to be tested with colour-fixed oils from old seed; if indeed beneficial, the implications of its use on a practical scale need to be worked out.

12. *Correlations between seed oil F.F.A., RL and colours of refined and bleached oils*: —Storage of expressed crude oil causes colour fixation without increasing the free acidity or the refining loss; hence, stored oils of low acidity will give rise to dark-coloured refined and bleached oils. However, oil storage is not normally practised, and hence such samples have been discarded when drawing the correlations here illustrated between refining loss and refined and bleach colours. Samples of varying F.F.A., refined over the last few years were divided into groups, obviously erratic results eliminated, and the figures for F.F.A., RL and oil colours plotted graphically (Fig. 1) and shown in Table XII. The difference in the colours of refined and bleached oils, *i.e.*, the degree of bleaching possible, rapidly narrows as the F.F.A. increases; at about 9-10% F.F.A., it may well be found that bleaching of refined oil has little effect on colour.

3. STUDIES ON THE REFINING OF COTTONSEED OIL

PART I. PRELIMINARY STUDIES

By

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Studies have been made on some of the factors affecting refining, such as degumming prior to alkali refining, strength and excess of alkali, speed of agitation on the refining loss and the optimum strength and excess of alkali required for refining crude cottonseed oil in general. Studies have also been made on the relative merits of dry and wet refining of cottonseed oil. Data are presented and discussed.

Introduction

Crude cottonseed oil, as such, is unsuitable for edible purposes, unlike most other edible oils. It is more difficult to refine this oil for the removal of colour than most other common edible oils. It is observed that the colour of the crude cottonseed oil produced in India is darker than that of the oil produced in the U.S.A. Further, many Indian mills directly crush whole cottonseed, without subjecting it to the usual preliminary treatment of delinting, dehulling, etc. The oil thus produced is darker in colour than oil produced by the usual process and hence more difficult to refine than the other. There is, therefore, need and urgency to work out suitable methods for refining crude cottonseed oil, so as to obtain an edible oil satisfying the accepted standards. The present paper deals with some preliminary work carried out in our Institute during the years 1954-56. The effect of some factors such as degumming the oil prior to refining, and strength and excess of alkali and speed of agitation in refining of cottonseed oil, are studied in the present work. The relative merits of dry and wet methods of refining have also been studied.

Previous Work

Sharma and Lal[1] carried out some tests on the refining of cottonseed oil, using different concentrations of caustic soda solutions. Fash[2] studied the caustic refining of cottonseed and other vegetable oils and concluded that the concentration of caustic solution required, the amount of excess caustic used, the length of time of mixing the oil-soapstock mixture in the cold and the oil content of the soapstock are governed by the amount and kinds of phosphatides present in the oil. He has also explained the mechanism of the procedures involved in the caustic refining of oils. Cavanagh[3] described a method for removing colour from neutralised and degummed cottonseed oil on re-refining. He has shown that colour removed is directly correlated to (a) concentration of sodium hydroxide solution, (b) length of time of agitation, and (c) speed of agitation in R.P.M. He also found that the degree of colour removal is inversely correlated with the temperature of the oil during agitation with sodium hydroxide solution. It is reported that the above laboratory observations have been put to practical use with satisfactory results. Kroonen and Feuge[4] made similar but more detailed studies and while confirming several of the results of Cavanagh, concluded that there are optimum speeds and times of agitation beyond which further removal of colour is very little. They also found that the colour removal in re-refining increases directly with the increase in temperature between 15° and 65°C and that losses by the high-shear and conventional methods of re-refining were almost identical. Some preliminary work on refining of cottonseed oil using different strengths of alkali was carried out earlier by the authors.[5] Harigopal and Rao[6] in some preliminary studies on the factors influencing refining have observed that refining loss increases and the refined oil colour is reduced with increase in the percentage excess of lye upto 300% and that beyond this limit the refining loss and colour reduction are practically constant.

As regards the desirability of degumming cottonseed oil prior to refining in order to reduce refining loss, opinion seems to be divided among refiners,[7] as several people maintain that the combined losses from the degumming and re-refining stages are greater than that in straight-alkali refining. On the other hand, others believe that if degumming is properly carried out, the combined refining loss is less than the normal refining loss. Besides the refining loss, there are other advantages in degumming cottonseed oil prior to refining, *viz.*, degummed oil shows a lower degree of colour reversion than crude oil, the soapstock obtained after degumming and refining has a lighter colour than that obtained in normal refining, and the phosphatides and gums separated are suitable for producing commercial lecithin or for incorporation in the meal or other products used for animal feeding. Deacon and Wamble[8] actually found that the degumming of screw-pressed cottonseed oil, followed by refining, gives a higher yield of refined oil than in the normal refining of the crude oil. The Short-Mix caustic soda process developed by the De Laval Separator Company has, as its first stage, continuous degumming of cottonseed oil, centrifugal separating of the gums and then continuous refining with alkali. Thus, opinion seems to be veering round to the view that degumming of cottonseed oil, prior to alkali refining is, on the whole, advantageous.

Experimental Work

The refining studies described in this paper have been made both in the laboratory and on a pilot-plant scale. For the laboratory-scale work, a combined refining and bleaching apparatus made by G. Worthen Agee, Memphis, U.S.A., according to the specifications given in the American Oil Chemists' Society Method Ca 9a-41 was used. The Method Ca 9a-52 has been adopted for refining, except for a few experiments made for studying the effect of speed of agitation. The pilot-plant studies have been made on a 0.33-ton capacity combined refining and bleaching vessel fitted with variable speeds of agitation and vacuum connection. The De Laval Laboratory refining and bleaching unit of 2 gallons capacity is also used in these refining studies. Refining work was carried out on 16 different crude cottonseed oils produced in our pilot-plant and from outside mills.

Degumming of Cottonseed Oil Prior to Refining

It is found from the studies made at this Institute that freshly-produced crude cottonseed oils contain 0.46% to 2.74% of phosphatides[9,10] determined spectrophotometrically. To study how far the prior removal of the phosphatide materials from the crude oil will help its subsequent refining, samples of freshly-produced crude cottonseed oils were obtained from different mills in the country and degummed, and the phosphatides recovered were isolated and estimated as acetone-insolubles by the method described in an earlier paper.[11] The crude and the corresponding degummed oils were refined in all these cases and the refining losses determined. The data are given in Table I.

Effect of Strength of Alkali on Refining

Refining was carried out on six samples of crude cottonseed oils, using in each case three different strengths of sodium hydroxide solutions, namely, 16° Bé, 18° Bé and 20° Bé lyes, using in each case an excess of 80 per cent of maximum, following the procedure for expeller oils given in the A.O.C.S. Method. Depending on F.F.A., this works out to 263 to 394% excess alkali over that required to exactly neutralise the free fatty acids. The data are presented in Table II.

Effect of Speed of Agitation During Refining

Three different samples of cottonseed oil were refined, closely following the A.O.C.S. Method for expeller oils, using four sets of different speeds in refining each oil. Higher speeds are used during the addition of the alkali and subsequent agitation for 45 minutes, when the rate of agitation is reduced and heat applied. Agitation is stopped altogether when proper break is obtained. The two speeds of 75-75 R.P.M. and 250-75 R.P.M. were applied in an A.O.C.S. refining apparatus, and the other two speeds of 500-150 R.P.M. and 750-150 R.P.M. were applied using a Kestner stirrer of fractional H.P. in an improvised arrangement. The refining data are given in Table III. The refined oil colours in each case were read on a Lovibond Tintometer. However, the colour measurements are not given in the Table as practically no difference in the colour readings was observed by changing the speeds of agitation within the limits tried in these experiments.

Studies on the Optimum Strength and Excess of Alkali for Refining Crude Cottonseed Oils

Although it is a common experience to the vegetable oil refiner that different batches of the same oil differ from each other in their behaviour during refining, it would be helpful if optimum conditions are worked out, in a general way, for refining crude cottonseed oil, as it will serve as a guide and a starting point to the refiners in the mills. With this object in view, two different cottonseed oils produced in our pilot-plant and one sample obtained from M/s. Sundatta Cottonseed Utilisation Ltd., Hubli, were each refined, using caustic lyes of three different strengths. Refining was also done using different excess percentages of each strength of lye, ranging from 50 to 350% over the theoretical quantity of the caustic required to neutralise the F.F.A. in the oil. In select cases, re-refining of the refined oils was done using 20° Bé and 40° Bé (and in one case 16° Bé) lyes. The re-refining was done only on two samples, as in the third case very light-coloured oils were obtained even by a single refining. The refining and re-refining data on these three oils are given in Table IV, V and VI respectively.

Relative Merits of Dry and Wet Methods of Refining Cottonseed Oil

In U.S.A., the dry method is almost always employed for cottonseed oil refining with quite satisfactory results. In India, the wet method of refining is almost universally practised for refining all vegetable oils and probably because of this tradition and experience, crude cottonseed oil is also refined mostly by the wet method; the dry and wet methods of refining cottonseed oil followed by us are those described in "Cottonseed and Cottonseed Products" edited by A. E. Bailey, and in "Industrial Oil and Fat Products" by A. E. Bailey, with slight modifications. Two gallons each of two different crude cottonseed oils were refined and re-refined in a De-Laval refining unit, both by the dry and the wet methods. On one of these oils, the centrifugal method of refining was also done. The refined oils were re-refined with 20° Bé and 40° Bé lyes and the re-refined oils were bleached. The refining data are given in Table VII.

Two different crude oils (700 lb. in each lot) were also refined in the combined refining and bleaching vessel both by the dry and wet methods. The refined oils were also re-refined and bleached. The refining data are given in Table VIII.

TABLE I

Data on the Refining of Crude and Corresponding Degummed Cottonseed Oils

Sample No.	F.F.A. (Per cent)		Phosphatide content (as acetone-insolubles) per cent	R. L. (Per cent)		Decrease in R. L. per cent	Colour of the refined oil on 0.25–inch cell	
	Crude oil	Degummed oil		With Crude oil	With Degummed oil		From crude oil	From degummed oil
S. 12	2.10	2.11	0.02†	8.5	8.5	...	15.2Y+4.1R (56.2)*	15.2Y+4.0R (55.2)*
S. 14	1.47	1.53	0.56	6.4	6.2	3.16	...	...
S. 15	2.43	2.43	0.91	8.1	7.5	7.41	...	...
S. 20	2.20	...	0.35	6.7	6.3	5.97	30.0Y+3.2R (62)	30.0Y+3.1R (61)
S. 21	2.40	...	0.33	8.8	8.3	5.68	22.0Y+2.5R (47)	22.0Y+2.4R (46)
S. 22	3.30	...	0.64	10.7	10.3	3.74	10.3Y+1.4R (24.3)	10.3Y+1.3R (23.3)
S. 23	1.50	...	0.56	7.5	7.2	4.00	8.4Y+1.1R (19.4)	8.4Y+1.1R (19.4)

* Colour of this sample read in a 1–inch cell.

† Low phosphatide content due to the oil sample being a settled one.

Figures in brackets in the last column represent colour units in terms of Y+10R.

R. L. = Refining loss.

TABLE II

Refining Data Using Different Strengths of Alkali on 6 Different Samples of Crude Cottonseed Oils

Sample No.	Crude oil F.F.A. Per cent	R. L. (Per cent) using alkali			Colour of refined oil on 1-inch cell		
		16°Bé*	18°Bé*	20°Bé*	16°Bé	18°Bé	20°Bé
S. 6	2.2	5.6	9.0	11.3	15.0Y+3.6R (51.0)	14.7Y+3.5R (49.7)	14.5Y+3.3R (47.5)
S. 7	1.3	5.9	7.0	8.2	18.0Y+4.6R (64.0)	17.8Y+4.5R (62.8)	17.6Y+4.4R (61.6)
S. 8	1.2	4.4	5.9	6.2	16.5Y+2.9R (45.5)	16.4Y+2.7R (43.4)	16.2Y+2.5R
S. 10	1.7	4.9	6.3	6.6	13.2Y+4.2R (55.2)	13.0Y+4.1R (54.0)	12.8Y+4.0R (52.8)
S. 11	1.5	5.5	6.4	6.7	14.2Y+4.4R (58.2)	14.0Y+4.3R (57.0)	13.8Y+4.1R (54.8)
S. 12	2.1	7.2	8.4	8.7	15.5Y+4.1R (56.5)	15.3Y+4.0R (55.3)	15.0Y+3.8R (53.0)

* Excess of alkali used in each case is 80% of Maximum as per A.O.C.S. Method Ca 9a-52 for expeller cottonseed oil.

Figures in brackets represent colour units in terms of Y+10R.

R. L.=Refining loss.

TABLE III

Refining Data Obtained with Different Speeds of Agitation

Sample No.	Crude oil F.F.A. Per cent	R. L. (Per cent) with R.P.M. used for agitation in refining			
		75-75	250-75	500-150	750-150
S. 10	1.7	6.8	6.2	6.0	5.6
S. 11	1.5	6.5	6.2	5.6	5.7
S. 12	2.1	7.6	7.4	7.6	7.4

TABLE IV

Refining and Re-refining Data on Sample S.25 of Cottonseed Oil with Different Strengths and Excess of Alkali

Crude Oil F.F.A. 1.91%. Crude Oil Colour in 0.25-inch cell: 122Y + 21R (332)

Refining Data		Re-refining Data			Colour in 0.25-inch cell		
Strength and excess of alkali used	R. L. Per cent	Strength and amount of alkali used	R. L. on wt. of crude oil started with Per cent	Total R. L. Per cent	Refined oil	Re-refined oil	Re-refined & bleached oil
12° Bé (100% excess)	5.60	...	...	...	Not measured	...	...
12° Bé (200% excess)	6.10	...	...	...	15.2Y+3.0R (45.2)	...	...
16° Bé (50% excess)	4.85	1.5% 40° Bé lye	4.76	9.61	21.0Y+2.0R (41.0)	15.0Y+3.1R (46.0)	9.9Y+1.5R (24.9)
16° Bé (75% excess)	5.36	do	4.37	9.73	20.4Y+2.0R (40.4)	14.2Y+2.9R (43.2)	9.6Y+1.4R (23.6)
16° Bé (100% excess)	5.60	do	4.25	9.85	20.0Y+2.0R (40.0)	13.2Y+2.7R (40.2)	8.5Y+1.1R (19.5)
16° Bé (200% excess)	6.40	do	4.12	8.89	15.0Y+2.3R (38.0)	11.2Y+1.3R (24.2)	5.3Y+0.5R (10.3)
		5.0% of 16° Bé lye	2 49	10.52	do	11.2Y+1.7R (28.2)	6.3Y+0.6R (12.3)
20° Bé (100% excess)	6.00	...	...	...	20.0Y+2.0R (40.0)	...	...
16° Bé (80% Maximum)[1]	7.35	...	...	...	12.0Y+1.9R (31.0)	...	...
20° Bé (80% Maximum)[1]	7.25	...	...	...	11.8Y+1.6R (27.8)	...	...
20° Bé (Maximum	8.60	...	...	..	11.6Y+1.3R (24.6)	...	...

1. Excess caustic corresponds to 256% over theoretical requirement.
2. do to 345% do

Figures in brackets in the last column represent colour units in terms of Y+10R.

R. L.=Refining loss.

TABLE V

Refining and Re-refining Data on Sample S. 26 of Cottonseed Oil with Different Strengths and Excess of Alkali

Crude Oil F.F.A. 6.0%. Crude Oil Colour in 0.25-inch cell: 71 Y+32R (391)

Refining Data		Re-refining Data			Colour with ¼-inch cell		
Strength and excess of alkali used	R. L. Per cent	Strength and amount of alkali used	R. L. calculated on wt. of crude oil started with Per cent	Total R. L. Per cent	Refined oil	Re-refined oil	Re-refined & bleached oil
12° Bé (100% excess)		No proper break could be obtained					
12° Bé (150% excess)	22.50	....	...	...	10.4Y+2.0R (30.4)	..	...
12° Bé (200% excess)	24.00	...	...	..	10.0Y+1.5R (25.0)	...	...
16° Bé (100% excess)	22.80	..	...	...	10.2Y+1.4R (24.2)	...	..
16° Bé (150% excess)	23.25	2.0% of 20° Bé lye	2.40	25.65	9.8Y+1.2R (21.8)	8.6Y+0.8R (16.8)	2.3Y+0.3R (5.3)
16° Bé (200% excess)	24.30	do	2.12	26.42	9.6Y+1.0R (19.6)	8.6Y+0.7R (15.7)	2.2Y+0.2R (4.2)
20° Bé (100% excess)	24.00	do	2.39	26.39	10.0Y+1.3R (23.0)	8.8Y+0.8R (16.8)	2.3Y+0.3R (5.3)
20° Bé (150% excess)	29.88	do	2.10	31.98	9.4Y+1.1R (20.4)	8.7Y+0.6R (14.7)	2.2Y+0.3R (5.2)
20° Bé (200% excess)	37.50	...	...	...	9.0Y+1.0R (19.0)	...	...

Figures in brackets in last column represent colour units in terms of Y+10R.

R. L.=Refining loss.

TABLE VI

Refining Data on Sample S. 32 of Cottonseed Oil with Different Strengths and Excess of Alkali

Crude Oil F.F.A. 7.0%, Crude Oil Colour in 0.25-inch cell: 102 Y + 64R (742)

Refining Strength and excess of caustic lye used	R. L. Per cent	Colour in 0.25-inch cell	
		Refined oil	Refined & bleached oil
16° Bé (200% excess)	30.35	9.3Y+0.9R (18.3)	2.4Y+0.3R (5.4)
18° Bé (150% excess)	31.20	9.2Y+0.9R (18.2)	2.3Y+0.2R (4.3)
18° Bé (200% excess)	36.85	8.7Y+0.8R (16.7)	2.1Y+0.2R (4.1)
20° Bé (150% excess)	36.30	8.7Y+0.8R (16.7)	2.1Y+0.2R (4.1)
20° Bé (200% excess)	46.20	8.4Y+0.7R (15.4)	2.0Y+0.2R (4.0)
20° Bé (Maximum)†	35.20	9.0Y+0.8R (17.0)	2.3Y+0.2R (4.3)

† Excess caustic 139% over theoretical requirement.

* Figures in brackets in last column represent colour units in terms of Y+10R.

R. L.=Refining loss.

TABLE VII

Refining and Re-refining Data Obtained by Dry and Wet Methods of Refining of Two Samples of Crude Cottonseed Oils on the De Laval Refining Unit

Sample No.	Crude oil F.F.A. Per cent	Process employed	Refining Data		Re-refining Data		Total R.L. Per cent	Colour in 0.25-inch cell			
			Strength and excess of lye used	R. L. Per cent	Strength and amount of lye used	R. L. calculated on wt. of crude oil started with Per cent		Crude oil	Refined oil	Re-refined oil	Bleached oil
S. 25	1.91	Dry	16° Bé lye (200% excess)	7.1	3.0% of 20° Bé lye	2.39	9.49	122Y+21R (332)	14.2Y+3.1R (45.2)	12.4Y+1.8R (30.4)	7.5Y+1.0R (17.5)
		Wet	do	9.1	do	3.73	12.83	do	13.5Y+2.6R (39.5)	11.2Y+1.6R (27.2)	6.6Y+0.9R (15.6)
T 29	2.98	Dry	16° Bé lye (150% excess)	15.94	1.5% of 40° Bé lye	5.70	21.64	91Y+10R (191)	9.4Y+2.3R (32.4)	9.0Y+1.2R (21.0)	3.0Y+0.3R (6.0)
		Wet	do	18.75	do	22.71†	41.64	do	9.8Y+1.9R (28.8)	9.2Y+1.3R (22.2)	3.6Y+0.5R (8.6)
		Centrifugal	do	18.44	do	2.44	20.88	do	9.2Y+1.8R (27.2)	8.8Y+1.7R (25.8)	5.0Y+0.7R (12.0)

† An exceptional case; generally such a high loss on re-refining does not occur.

Figures in brackets in last column represent colour units in terms of Y+10R.

R. L.=Refining Loss.

TABLE VIII

Refining and Re-refining Data Obtained by Dry and Wet Methods of Refining of Two Samples of Crude Cottonseed Oils on the Combined Refining and Bleaching Vessel

Sample No.	Crude oil F.F.A. Per cent.	Process employed	Refining Data		Re-refining Data		Total R. L. Per cent	Colour in 0.25-inch cell			
			Strength and excess of lye used	R. L. Per cent	Strength and amount of lye used	R. L. calculated on wt. of crude oil started with Per cent		Crude oil	Refined oil	Re-refined oil	Bleached oil
S. 25	1.9	Dry	16° Bé lye (200% excess)	7.1	3.0% of 20° Bé lye	3.5	10.6	122Y+21R (332)	15,0Y+1.8R (33.0)	9.5Y+1.3R (22.5)	*
		Wet	do	7.5	1.5% of 40° Bé lye	4.0	11.5	do	17.2Y+1.9R (36.2)	13.2Y+1.7R (30.2)	4.2Y+0.5R (9.2)
S. 32	7.00	Dry	18° Bé lye (150% excess)	40.43	3.0% of 20° Bé lye	2.01	42.44	102Y+64R (142)	9.7Y+0.9R (16.7)	7.4Y+0.7R (14.4)	18Y+0.3R (4.8)
		Wet	do	53.44	do	3.93	57.37	do	10.2Y+0.9R (19.2)	8.7Y+0.5R (13.7)	2.0Y+0.3R (5.0)

* There was some darkening of the colour of the oil during bleaching because an old sample of earth was used.

Figures in brackets in the last column represent colour units in terms of Y+10R.

R. L.=Refining loss.

Discussion of the Results

(i) From the data in Table I the F.F.A.s of the crude and the corresponding degummed oils in two out of the three cases determined do not differ. The higher F.F.A. of the degummed oil in the third case is considered to be an experimental error in determining the F.F.A. The observation that the crude and degummed oils have the same F.F.A. may perhaps be attributed to the low content of gums (phosphatides) of the samples examined. (However, in our subsequent work, we have invariably observed a slight but not very significant reduction in F.F.A. on degumming crude cottonseed oils). It is seem from Table I that the refining loss of all the degummed oils is slightly lower than that of the corresponding crude oils. The last column in Table I indicates that no significant difference is found in the colours of the refined oils obtained from either the crude or the degummed oils. The data obtained in this batch refining work indicate that the combined refining loss in the degumming and refining stages is higher than the refining loss obtained by directly refining the crude oil in one stage. Further studies on this aspect are in progress.

(ii) From the data in Table II, it is noticed that while the reduction in colour is greater with the use of a higher strength of alkali in refining, the refining loss is also greater. It may, however, be noticed that the reduction in colour is not commensurate with refining loss involved by use of alkali of higher strength than 16°Bé.

(iii) From the data in Table III, it is seen that there is a progressive reduction in refining loss with increase in the speed of agitation of the oil during refining, from 75-75 R.P.M. to 750-150 R.P.M. This result is in conformity with the earlier findings of Cavanagh.[3]

(iv) From the data presented in Tables IV, V, VI, and also in Table II, it is seen that the use of 16°Bé alkali with 200% excess gave the best refining results, taking both the refining loss and the refined oil colour into consideration. In refining sample No. 32, equally good results are obtained either with 16°Bé alkali and 10% excess, or with 18°Bé alkali and 150% excess. The use of 12° Bé in the case of the two oils either did not give a break (*vide* Tables IV and V) or gave oils of higher colour, whereas the use of 20°Bé lye resulted in higher refining losses, without a corresponding significant reduction in colour. The re-refining work done in selected cases indicated that re-refining with 20° Bé alkali, using 2% lye on the weight of the refined oil is preferable to using 1.5% lye of 40° Bé. The re-refining loss is considerably lower in the former than in the latter case, without any significant difference in the colour reduction.

(v) From the data given in Tables VII and VIII, it is seen that lower refining losses in all cases were obtained by the dry rather than by the wet method of refining, and on the whole a greater reduction in colour of the refined oils was obtained by the dry method.

We would like to state here that the oils used in the refining work (Tables IV to VIII) are very old samples which would partly explain the high refining losses and dark-coloured refined oils obtained.

Summary of Results

(1) The degumming of crude cottonseed oils prior to refining results in a slightly lower refining loss than when done by straight refining, with the additional advantage of recovering valuable by-product phosphatides.

(2) The higher the strength and the greater the excess of alkali used, the greater the colour reduction in refining crude oils. But the refining losses also increase as the strength and excess of alkali used are increased.

(3) The use of a higher speed of agitation at the refining stage results in lower refining losses. No colour reduction, however, was observed within the range of speeds tried.

(4) In general, use of 16° Bé lye and 200% excess (over the theoretical requirement of alkali) for refining, and 2% of 20° Bé lye for re-refining, are found to give optimum refining results. Sometimes the use of 18° Bé alkali with 150-200% excess gives good results.

(5) The dry method of refining is found on the whole to give better results than the wet method of refining for cottonseed oils.

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4. STUDIES ON THE REFINING OF INDIAN COTTONSEED OIL

PART II. SOME OPTIMUM CONDITIONS OF REFINING

By

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Studies have been undertaken to find out the optimum strength and excess of alkali required for refining and re-refining of 9 different samples of Indian expeller-pressed crude cottonseed oils obtained from desi and American types of cottonseed. All the refined oils obtained in these studies were re-refined with both 1% of 40° Bé and 2% of 20° Bé alkali on the weight of the refined oils. It is concluded that for refining the use of 18° Bé alkali with 150% excess over the theoretical amount required to neutralise the F.F.A. and for re-refining the use of 2% of 20° Bé alkali on the weight of the refined oils gave the best results. In all cases, the use of 2% of 20° Bé alkali for re-refining gave better results than when 1% of 40° Bé alkali was used, taking into consideration both the re-refining losses and the final bleach colours of the re-refined oils.

Introduction

In the previous paper[1] studies made on some factors affecting the refining loss in refining cottonseed oil, such as degumming prior to alkali refining, strength and excess of alkali and speed of agitation have been reported. In this paper, work has been directed to determining the optimum strength and excess of alkali required for neutralising the free fatty acids during refining, and the strength and quantity of alkali required for re-refining.

Previous work done in India dealing with the aspects studied in the earlier paper[1] has already been referred to in that paper. Bhasin and Aggarwal[2] have reported the refining and re-refining data obtained by them on one sample of cottonseed oil, using 15.0% (*i.e.*, 20.8° Bé) alkali of 0.5% excess (*i.e.*, 61% excess) for refining, and 20% solution containing 1.5 gms of dry alkali (*i.e.* 1.5% of 26.5° Bé lye on the weight of refined oil) for re-refining 500 gm. of the refined oil. Narayana Rao and Kuppuswamy[3] reported refining of cottonseed oil according to official methods of the A.O.C.S., and re-refining using 1% of 25% alkali (31.5° Bé lye) on the weight of refined oil. Some preliminary work done in this direction by this Institute was also reported earlier.[4] Apart from the above work on the general refining of Indian cottonseed oils, studies on the use of some chemicals in reducing the refining losses was reported by us.[5] More recently, a process involving the preliminary treatment of the crude oil with a solution of borax or like material, which results in the formation of an insoluble complex with gossypol and other pigments and renders the oil amenable to normal refining subsequently, has been patented by Kailash Chander and T. R. Seshadri, and the economics of the process are being studies at the Shri Ram Institute for Industrial Research, Delhi.[6]

TABL

Full Refining Data on 9 Samples of Crude Cottonsee

Sample No.	Variety of the seed & details of processing	Crude Oil		Refining data			Re-refinin	
		F.F.A. Per cent	Colour in 0.25-inch cell	Strength and excess of lye used	R.L. Per cent	Refined oil colour in 0.25-inch cell	R.L. Per cent	Total R.L. Per cent
	1	2	3	4	5	6	7	8
39	Seed from Tadpatri, cleaned, whole seed crushed.	2.43	196Y+36R (556)	16°Bé lye 200% excess	7.30 (3.00)*	14.5Y+1.1R (25.5)	7.35	14.65 (6.03)*
				18°Bé lye 150% excess	7.00 (2.88)*	15.0Y+1.3R (28.0)	7.74	14.74 (5.93)*
40	Same seed, cleaned seed crushed by full modern technique.	3.54	86Y+14R (226)	16°Bé lye 200% excess	13.80 (3.81)*	13.8Y+0.9R (22.8)	5.17	18.97 (5.34)*
				18°Bé lye 150% excess	14.50 (4.10)*	14.2Y+0.9R (23.2)	5.42	19.92 (5.63)*
43	Same seed, cleaned seed delinted, broken and crushed.	3.10	204Y+32R (524)	16°Bé lye 200% excess	8.90 (2.87)*	14.5Y+1.1R (25.5)	8.20	17.10 (5.52)*
				18°Bé lye 150% excess	8.30 (2.68)*	14.8Y+1.2R (26.8)	9.17	17.47 (6.62)*
44	Laxmi seed from Adoni, cleaned crushed by full modern technique.	4.65	364Y+32R (684)	16°Bé lye 200% excess	17.30 (3.72)*	12.0Y+0.4R (16.0)	5.10	22.40 (4.82)*
				18°Bé lye 150% excess	15.90 (3.42)*	12.1Y+0.5R (17.1)	4.35	20.25 (4.36)*
45	Same seed, cleaned, whole seed crushed.	2.03	410Y+36R (770)	16°Bé lye 200% excess	5.20 (2.56)*	24.4Y+0.6R (30.4)	6.64	11.84 (5.83)*
				18°Bé lye 150% excess	5.10 (2.51)*	24.7Y+0.7R (31.7)	5.38	10.48 (5.16)*
46	Same seed, cleaned seed delinted, broken and crushed.	2.45	392Y+32R (712)	16°Bé lye 200% excess	7.25 (2.96)*	23.2Y+0.5R (28.2)	7.42	14.67 (5.98)*
				18°Bé lye 150% excess	6.65 (2.71)*	24.2Y+0.5R (29.2)	6.67	13.32 (5.44)*
47	Vijay seed from Dabhoi, cleaned seed crushed by full modern technique.	2.27	180Y+14R (320)	16°Bé lye 200% excess	7.85 (3.46)*	12.1Y+1.1R (23.1)	6.75	14.60 (6.43)*
				16°Bé lye 80% Max. 220% excess	7.80 (3.46)*	12.1Y+1.2R (23.1)	9.22	17.02 (7.50)*
				18°Bé lye 150% excess	7.35 (3.24)*	12.1Y+1.1R (24.1)	5.56	12.91 (5.69)*

I

Oils with Different Strengths and Excesses of Alkali

data with 1.0% of 40° Bé lye			Re-refining data with 2.0% of 20° Bé lye				
Re-refined oil colour in 0.25-inch cell	Colour of bleached oil		R.L. Per cent	Total R.L. Per cent	Re-refined oil colour in 0.25-inch cell	Colours of bleached oils	
	In 0.25-inch cell	In 1-inch cell				In 0.25-inch cell	In 1-inch cell
9	10	11	12	13	14	15	16
13.4Y+0.4R (17.4)	1.5Y+0.1R (2.5)	7.8Y+0.5R (12.8)	3.02	10.32 (4.25)*	13.7Y+0.5R (18.7)	1.6Y+0.1R (2.6)	8.0Y+0.6R (14.0)
14.2Y+0.5R (19.2)	1.5Y+0.1R (2.5)	7.8Y+0.5R (12.8)	2.73	9.73 (4.00)*	14.4Y+0.6R (20.4)	1.6Y+0.1R (2.6)	8.0Y+0.6R (14.0)
12.2Y+3.4R (16.2)	1.4Y+0.1R (2.4)	7.2Y+0.4R (11.2)	3.68	17.48 (4.94)*	12.4Y+0.4R (16.4)	1.5Y+0.1R (2.5)	7.9Y+0.5R (12.9)
12.4Y+0.4R (16.4)	1.5Y+0.1R (2.5)	7.7Y+0.5R (12.7)	2.96	17.36 (4.90)*	12.7Y+0.4R (16.7)	1.6Y+0.1R (2.6)	8.0Y+0.6R (14.0)
12.6Y+0.4R (16.6)	1.5Y+0.1R (2.5)	7.8Y+0.5R (12.8)	3.64	12.54 (4.04)*	12.8Y+0.5R (17.8)	1.6Y+0.1R (2.6)	8.0Y+0.6R (14.0)
12.9Y+0.4R (16.9)	1.5Y+0.1R (2.5)	7.8Y+0.5R (12.8)	3.30	11.60 (3.74)*	13.1Y+0.5R (18.1)	1.6Y+0.1R (2.6)	8.0Y+0.6R (14.00)
4.2Y+0.4R (8.2)	0.8Y+0.1R (1.8)	3.2Y+0.3R (6.2)	3.58	20.88 (4.49)*	4.4Y+0.4R (8.4)	0.8Y+0.1R (1.8)	3.2Y+0.3R (6.0)
4.2Y+0.4R (8.2)	0.8Y+0.1R (1.8)	3.2Y+0.3R (6.2)	2.94	18.84 (4.05)*	4.4Y+0.4R (8.4)	0.8Y+0.1R (1.8)	3.2Y+0.3R (6.2)
7.0Y+0.4R (11.0)	1.0Y+0.1R (2.0)	4.0Y+0.3R (7.0)	3.95	9.15 (4.51)*	7.2Y+0.4R (11.2)	1.0Y+0.1R (2.0)	4.0Y+0.3R (7.0)
7.1Y+0.4R (11.1)	1.0Y+0.1R (2.0)	4.0Y+0.3R (7.0)	3.48	8.58 (4.23)	7.3Y+0.4R (11.3)	1.0Y+0.1R (2.0)	4.0Y+0.3R (7.0)
6.4Y+0.4R (10.4)	0.9Y+0.1R (1.9)	3.6Y+0.3R (6.6)	3.94	11.19 (4.57)*	6.6Y+0.4R (10.6)	0.9Y+0.1R (1.9)	3.6Y+0.3R (6.6)
.4Y+0.4R (10.4)	0.9Y+0.1R (1.9)	3.6Y+0.3R (6.6)	3.27	10.02 (4.09)*	6.6Y+0.4R (10.6)	0.9Y+0.1R (1.9)	3.6Y+0.3R (6.6)
.3Y+0.6R (15.3)	1.6Y+0.1R (2.6)	6.0Y+0.5R (11.0)	3.99	11.84 (5.22)*	9.7Y+0.8R (17.7)	1.7Y+0.1R (2.7)	6.3Y+0.5R (11.3)
.6Y+0.6R (15.6)	1.6Y+0.1R (2.6)	6.2Y+0.5R (11.2)	2.46	10.26 (4.52)*	9.8Y+0.8R (17.8)	1.7Y+0.1R (2.7)	6.3Y+0.5R (11.3)
.7Y+0.6R (15.7)	1.6Y+0.1R (2.6)	6.1Y+0.5R (11.1)	3.24	10.59 (4.67)*	9.8Y+0.8R (17.8)	1.7Y+0.1R (2.7)	6.3Y+0.5R (11.3)

TABLE

1	2	3	4	5	6	7	8
47 *(Contd.)* Vijay seed from Dabhoi, cleaned seed crushed by full modern technique.			20°Bé lye 80% Max. 220% excess	9.50 (4.18)*	11.8Y+1.0R (21.8)	8.15	17.65 (7.79)*
			20°Bé lye Maximum 300% excess	11.20 (4.93)*	11.6Y+0.9R (20.6)	7.99	19.19 (8.45)*
48 Kalyan seed from Viramgam, cleaned seed crushed by full modern technique.	1.53	121Y+8R (201)	16°Bé lye 200% excess	7.60 (4.97)*	21.0Y+0.6R (27.0)	5.55	13.15 (8.59)*
			16°Bé lye 80% Max. 310% excess	9.65 (6.31)*	20.3Y+0.6R (26.3)	9.94	19.69 (12.87)*
			18°Bé lye 150% excess	7.40 (4.84)*	21.5Y+0.7R (28.5)	6.11	13.51 (8.83)*
			20°Bé lye 80% Max. 310% excess	11.20 (7.32)*	17.2Y+0.6R (23.2)	7.99	19.19 (12.54)*
			20°Bé lye Maximum 415% excess	11.60 (9.55)*	15.2Y+0.5R (20.2)	15.62	27.22 (17.78)*
49 Jayadhar seed from Raichur, cleaned seed crushed by full modern technique.	2.83	223.6Y+26R (484)	16%Bé lye 200% excess	9.40 (3.32)*	12.4Y+0.7R (19.4)	9.97	19.37 (6.85)*
			16°Bé lye 250% excess	10.00 (3.53)*	11.8Y+0.6R (17.8)	9.90	19.90 (7.03)*
			18°Bé lye 150% excess	8.70 (3.03)*	12.7Y+0.9R (21.7)	6.39	15.09 (5.33)*
			18°Bé lye 200% excess	9.50 (3.36)*	12.2Y+0.7R (19.2)	10.61	20.67 (7.31)*

R.L.=Refining Loss.

Figures in brackets represent colour units in terms of Y+10R.

* Figures in brackets marked with asterisk denote refining factor (Refining factor=R.L./F.F.A.).

–(*Contd.*)

9	10	11	12	13	14	15	16
2Y+0.5R (14.2)	1.5Y+0.1R (2.5)	5.8Y+0.4R (9.8)	2.72	12.22 (5.38)*	9.6Y+0.6R (15.6)	1.6Y+0.1R (2.6)	6.2Y+0.5R (11.2)
.0Y+0.5R (14.0)	1.4Y+0.1R (2.4)	5.6Y+0.4R (9.6)	2.07	13.27 (5.82)*	9.4Y+0.6R (15.4)	1.5Y+0.1R (2.5)	5.9Y+0.4R (9.9)
0.4Y+0.5R (15.4)	2.0Y+0.2R (4.0)	9.0Y+0.7R (16.0)	4.25	11.85 (7.75)*	11.2Y+0.5R (16.2)	2.2Y+0.2R (4.2)	10.6Y+0.8R (18.6)
.8Y+0.5R (14.8)	1.8Y+0.2R (3.8)	8.2Y+0.6R (14.2)	3.07	12.72 (8.31)*	10.2Y+0.5R (15.2)	1.9Y+0.2R (3.9)	8.8Y+0.6R (14.8)
1.0Y+0.5R (16.0)	2.0Y+0.2R (4.0)	9.0Y+0.7R (16.0)	4.63	12.03 (7.86)*	11.5Y+0.6R (17.5)	2.2Y+0.2R (4.2)	10.4Y+0.8R (18.4)
.8Y+0.5R (13.8)	1.6Y+0.2R (3.6)	6.6Y+0.6R (12.6)	6.67	17.87 (11.68)*	9.2Y+0.5R (14.2)	1.7Y+0.2R (3.7)	6.8Y+0.6R (12.8)
.8Y+0.4R (11.8)	1.6Y+0.2R (3.6)	6.6Y+0.6R (12.6)	6.90	18.50 (12.09)*	8.2Y+0.4R (12.2)	1.7Y+0.2R (3.7)	6.8Y+0.6R (12.8)
.4Y+0.5R (13.4)	1.2Y+0.1R (2.2)	4.6Y+0.4R (8.6)	3.44	12.84 (4.54)*	8.8Y+0.5R (13.8)	1.2Y+0.1R (2.2)	4.8Y+0.4R (8.8)
9Y+0.5R (12.9)	1.2Y+0.1R (2.2)	4.6Y+0.4R (8.6)	3.15	13.15 (4.65)*	8.2Y+0.5R (13.2)	1.2Y+0.1R (2.2)	4.8Y+0.4R (8.8)
8Y+0.6R (14.8)	1.3Y+0.1R (2.3)	5.0Y+0.5R (10.0)	3.81	12.51 (4.42)*	9.0Y+0.6R (15.0)	1.3Y+0.1R (2.3)	5.2Y+0.4R (9.2)
4Y+0.5R (13.4)	1.3Y+0.1R (2.3)	5.2Y+0.5R (10.2)	5.13	14.63 (5.17)*	8.7Y+0.5R (13.7)	1.3Y+0.1R (2.3)	5.0Y+0.5R (10.0)

TABLE II

Summary of Refining data on 9 Samples of Indian Crude Cottonseed Oils, Refined with 16° Bé and 18° Bé and 150% Excess Caustic Soda

Sample No.	F.F.A. Per cent	Refining loss		Refined oil colours with 0.25-inch cell	
		With 16° Bé and 200% excess alkali Per cent	With 18° Bé and 150% excess alkali Per cent	Using 16° Bé lye and 200% excess (Y+10R)	Using 18° Bé lye and 150% excess (Y+10R)
39	2.43	7.30 (3.00)	7.00 (2.88)	25.5	28.0
40	3.54	13.80 (3.81)	14.50 (4.10)	22.8	23.2
43	3.10	8.90 (2.87)	8.30 (2.68)	25.5	26.8
44	4.65	17.30 (3.72)	15.90 (3.42)	16.0	17.1
45	2.03	5.20 (2.56)	5.10 (2.51)	30.4	31.7
46	2.45	7.25 (2.96)	6.65 (2.71)	28.2	29.2
47	2.27	7.85 (3.46)	7.35 (3.24)	23.1	24.1
48	1.53	7.60 (4.97)	7.40 (4.84)	27.0	28.5
49	2.83	9.40 (3.32)	8.70 (3.07)	19.4	21.7

Figures given within brackets represent refining factors.

TABLE III

Refining and Bleaching data on 9 Samples of Indian Crude Cottonseed Oils, Using 16° and 18° Bé lye for Refining and 2% of 20° Bé lye for Re-refining

Sample No.	F.F.A. of crude oil	Data on refining with 16° Bé lye with 200% excess and re-refining with 2% of 20° Bé lye			Data on refining with 18° Bé lye with 150% excess and re-refining with 2% of 20° Bé lye		
		Total R.L. Per cent	Re-refined oil colour*	Re-refined bleached colour*	Total R.L. Per cent	Re-refined oil colour*	Re-refined bleached colour*
39	2.43	10.30 (4.30)	18.7	2.6	9.70 (4.00)	20.4	2.6
40	3.54	17.50 (4.94)	16.4	2.5	17.40 (4.90)	16.7	2.6
43	3.10	12.50 (4.04)	17.8	2.6	11.60 (3.74)	18.1	2.6
44	4.65	20.90 (4.49)	8.4	1.8	18.80 (4.05)	8.4	1.8
45	2.03	9.20 (4.51)	11.2	2.0	8.60 (4.23)	11.3	2.0
46	2.45	11.20 (4.57)	10.6	1.9	10.00 (4.09)	10.6	1.9
47	1.88	11.84 (5.22)	17.7	2.7	10.59 (4.67)	17.8	2.7
48	1.53	11.85 (7.75)	16.2	4.2	12.03 (7.86)	17.5	4.2
49	2.83	12.84 (4.54)	13.8	2.2	12.51 (4.42)	15.0	2.3

Figures given in brackets represent refining factors.

* Colour readings are expressed as Y+10R units measured in a 0.25-inch cell on a Lovibond Tintometer.

TABLE IV

Comparative Data on Re-refining Losses and Bleached Colours of Oils Re-refined with 1% of 40° Bé lye (Refined Oils Derived from Crude Oils Refined with 16° Bé lye and 200% Excess, and 18° Bé lye and 150% Excess Respectively)

Sample No.		Refining loss		Re-refined and bleached oil colour			
		With 40° Bé Per cent	With 20° Bé Per cent	With 40° Bé 0.25-inch cell (Y+10R)	With 40° Bé 1-inch cell (Y+10R)	With 20° Bé 0.25-inch cell (Y+10R)	With 20° Bé 1-inch cell (Y+10R)
39	16°Bé	7.93	3.26	2.5	12.8	2.6	14.0
	18°Bé	8.33	2.93	2.5	12.8	2.6	14.0
40	16°Bé	6.00	4.94	2.4	11.2	2.5	12.9
	18°Bé	6.33	4.90	2.5	12.7	2.6	14.0
43	16°Bé	9.00	4.00	2.5	12.8	2.6	14.0
	18°Bé	10.00	3.60	2.5	12.8	2.6	14.0
44	16°Bé	6.17	4.33	1.8	6.2	1.8	6.2
	18°Bé	5.17	3.50	1.8	6.2	1.8	6.2
45	16°Bé	7.00	4.17	2.0	7.0	2.0	7.0
	18°Bé	5.67	3.67	2.0	7.0	2.0	7.0
46	16°Bé	8.00	4.23	1.9	6.6	1.9	6.6
	18°Bé	7.17	3.50	1.9	6.6	1.9	6.6
47	16°Bé	7.33	4.33	2.6	11.0	2.7	11.3
	18°Bé	6.00	3.50	2.6	11.0	2.7	11.3
48	16°Bé	6.00	4.60	4.0	16.0	4.2	18.6
	18°Bé	6.60	5.00	4.0	16.0	4.2	18.4
49	16°Bé	11.00	3.83	2.2	8.6	2.2	8.8
	18°Bé	7.00	4.17	2.2	10.0	2.3	9.2

TABLE V

Data on the Quantity of Dry Alkali Used for Refining and Re-refining, Expressed as Per cent of Dry Alkali on Weight of the Oil Refined

Sample No.	Refining		Re-refining	
	With 16° Bé and 200% excess Per cent	With 18° Bé and 150% excess Per cent	With 1% of 40° Bé lye Per cent	With 2% of 20° Bé lye Per cent
39	0.88	0.72	0.33	0.29
40	1.25	1.04	,,	,,
43	1.10	0.92	,,	,,
44	1.98	1.65	,,	,,
45	0.87	0.72	,,	,,
46	1.05	0.87	,,	,,
47	0.97	0.81	,,	,,
48	0.65	0.55	,,	,,
49	1.21	1.00	,,	,,

Experimental Work

Laboratory-scale refining work on 9 samples of Indian cottonseed oils, using different strengths and excess of alkali for refining and re-refining, was carried out on the laboratory combined refining-and-bleaching apparatus made according the specification given in the American Oil Chemists' Society Method Ca 9a-41, following the A.O.C.S. Method Ca 9a-52. For bleaching the re-refined oils, the A.O.C.S. Method was followed, except for using 4% Tonsil A.C.A. brand activated fuller's earth and 0.4% Darco S-51 brand activated carbon, in place of 6% of the Official earth.

Our earlier work[1] had shown that the use of 12° Bé lye either did not give a break or gave refined oils of a darker colour than those obtained using 16° Bé lye; hence alkali of this weak concentration was not used in the present work. 20° Bé lye with different excesses was used only in two cases, since higher refining losses, without the corresponding reduction in colour, had earlier been obtained by its use. Therefore, in the present work, 16° Bé lye and 18° Bé lye have been used, respectively with 200% excess and 150% excess alkali, in refining all the samples on a laboratory scale. The limiting of the excess of alkali to 200% and 150% above the theoretical requirement respectively is also based on the results obtained in our earlier work.[1] However, for purposes of comparison, refining with 16° Bé and 18° Bé lye with different excess alkali was done in a few cases.

All the refined oils were re-refined using 2.0% of 20° Bé lye and 1.0% of 40° Bé lye on the weights of refined oils taken. The complete refining and re-refining data obtained are presented in Table I.

Discussion of the Results

In order to facilitate discussion of the results in Table I, the refining data alone (*i.e.* refining loss and colour) on all the samples with 16° and 18° Bé alkali are given in Table II, refining and re-refining data on the samples (*i.e.*, total refining loss and re-refined and bleach oil colours) obtained with these two lyes and excess alkali are given in Table III, and comparative re-refining loss and re-refined and bleached oil colours in Table IV. In Table V is shown the weight per cent of alkali on the weight of oil refined corresponding to 16° Bé lye and 200% excess, 18° Bé lye and 150% excess, and 1% of 40° Bé lye and 2% of 20° Bé lye, for all the samples.

From the refining and re-refining data given in Table I, it will be seen that although when 16° Bé lye with 250% excess, 18° Bé lye with 200% excess, and 20° Bé lye at 80% of Maximum or of Maximum are used, lighter refined and re-refined oils are obtained, the corresponding re-refined and bleached oils are not significantly lighter than the re-refined and bleached oils obtained on refining with 16° Bé lye with 200% excess or 18° Bé lye with 150% excess. On the other hand, the total refining losses incurred in all the above cases are invariably higher than those obtained when 16° Bé with 200% excess or 18° Bé with 150% excess caustic is used. Moreover, a higher per cent alkali on the weight of oil is involved in the former cases than in the two latter cases. In other words, taking into consideration both the total refining loss and the final bleach colours, and the caustic soda involved, better results are obtained in all cases by using 16° Bé lye with 200% excess or 18° Bé lye with 150% excess, than when higher or lower concentration of alkali is used. Therefore, further discussion is confined to the results obtained with these two strengths and excesses of alkali.

From Table II it is seen that in all cases, the refining loss is less for the same oil when refined with 18° Bé lye and 150% excess alkali than when refined with 16° Bé lye and 200% excess alkali (except for sample No. 40). On the other hand, the refined oil Lovibond colours expressed as Y + 10R units are slightly higher in all cases when refined with 18°Bé lye (and 150% excess) than those obtained with 16°Bé lye (and 200% excess). From Table III, it can be seen that the total refining loss obtained by refining with 18°Bé lye and re-refining with 2% of 20°Bé lye (on the weight of refined oil) is lower in all cases (except for sample No. 48 and here only very slightly) than those obtained by refining with 16°Bé lye and re-refining with 2% of 20° Bé lye. Again, the re-refined oil colours are silghtly higher in the former than in the latter except in sample Nos. 44 and 40 in which they are the same. However, the bleach colours of the re-refined oils are practically the same in both cases for all the nine samples. Thus, it is clear that for these nine different samples of *desi* and American-type oils, refining with 18°Bé lye with 150% excess alkali gave better results than refining with 16°Bé lye with 200% excess caustic, taking into consideration both the total refining loss and the final bleach colours.

From the data given in Table V, it can be seen that the weight percentage of alkali present in 18°Bé lye and 150% excess, expressed on weight of the crude oil, is less in all nine cases than the corresponding value for 16°Bé lye and 200% excess alkali to the extent of 0.10 to 0.33%. In other words, when applied to plant operations, not only will better results be obtained on refining the crude oils with 18°Bé lye using 150% excess alkali, but the caustic soda required will also be less to the extent of about 2 to 7 lb. per ton of crude oil refined.

Re-refining of cottonseed oils has been recommended as a common and generally satisfactory method[7] for dark refined oil. For this purpose it is usual to use 1.0 to 1.5% of 40°Bé lye with full agitation for 15-20 minutes in the cold, reduce the agitation, raise the temperature of the contents of the kettle to 130-140°F and spray hot water at 180-200°F over the surface of the kettle; the agitation is now reduced considerably below medium speed and when the kettle is finished, agitation is cut off and the batch allowed to settle in the same manner as for a regular crude refining. The present results on laboratory-scale re-refining with 1% of 40°Bé lye and 2% of 20°Bé lye on the weight of refined oils in all cases are given in Table IV. It can be seen that the refining loss is uniformly higher when re-refining with 40°Bé lye than when done with 20°Bé lye, irrespective of the strengths and excess alkali employed. This difference in the refining loss is considerably higher in six out of the nine samples, and is appreciable in the case of the other three samples. The re-refined oil colours are naturally lighter with 40°Bé lye than with 20°Bé lye in all cases (*vide* Table I), but the differences in all cases are very small. The bleach colours of the re-refined oils are however, practically the same in both cases when measured in a 0.25-inch cell and are only slightly higher when measured in a 1-inch cell. Incidentally, it is found that slight differences in colour measurements are more difficult to observe when using a 0.25-inch cell than with a 1-inch cell; the differences are magnified still better when using a 5.25-inch cell.

From Table V, it will be seen that 1% of 40°Bé corresponds to 0.33% of dry sodium hydroxide on the weight of refined oil, while 2% of 20°Bé lye corresponds to 0.29% of dry sodium hydroxide. Hence, by re-refining with 1% of 40°Bé lye, more caustic is consumed than when 2% of 20°Bé lye is used, which also gave better results in all the cases studied than 40°Bé lye.

It has to be mentioned here that the above results obtained on the laboratory-scale may not be applicable to large-scale refining *in toto*. Generally speaking, however, they will give a good guidance in the selection of the strength and excess of alkali to be used in large-scale refining. The refining losses and refined oil colours are generally higher in large-scale operations than those obtained in the laboratory. But they are related to and vary directly as the results obtained in standard laboratory-refining operation, for a given oil and refining conditions. Therefore, while it may be necessary in the case of very dark refined oils to use 1 to 1.5% of 40°Bé lye for re-refining, generally 2% of 20°Bé lye may give more satisfactory results in many cases and hence is recommended for the normal practice of re-refining.

Summary and Conclusions

(1) Nine samples of different varieties of cottonseed oils have been refined with 16°Bé lye and 200% excess caustic, and 18°Bé lye and 150% excess. Three of these have also been refined with alkali of other strengths and excesses. The data obtained are presented.

(2) All the refined oils obtained were re-refined with 1% of 40°Bé lye and 2% of 20° Bé lye and bleached. The re-refining and bleaching data are also presented.

(3) From the results obtained, it is concluded that the use of 18°Bé with 150% excess gives the best results for refining of normal Indian cottonseed oils.

(4) Similarly, for re-refining, the use of 2% of 20°Bé lye is found to give better results than 1% of 40°Bé lye, and hence the use of 0.3 of 15% solution of sodium hydroxide (*i.e.*, 2% of 20°Bé caustic) on the weight of refined oils is recommended for normal oils; stronger alkali is to be used only for re-refining darker refined oils.

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5. REFINING OF WASHED COTTONSEED OIL FOR USE IN VANASPATI

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The paper describes the possibilities for extending cottonseed oil crushing and the precautions to be taken prior to refining in order to obtain an oil of good quality.

The washed cottonseed oil available at present can be re-refined by the dry or by the wet method. Both these methods as tried on the plant are described in detail. It is claimed that the wet or dilute lye method is more effective. The process of bleaching and hydrogenation has also been described. The hydrogenation was carried out at a low temperature and was found to be quite effective.

Introduction

India is the oldest and one of the largest producers of cottonseed in the world and the production of cottonseed is steadily going up. During the year 1956-57, 1.4 million tons of cottonseed were produced and in the Second Five-Year Plan it is envisaged that by 1960-61 more than two million tons of cottonseed will be available. However, it is surprising to note that at present only 6% of the total production of cottonseed is crushed, while in other cottonseed-producing countries like U.S.A. and U.S.S.R. more than 80% of the cottonseed produced is processed for the recovery of oil, linters, cake, etc.

There are several factors which have hindered the growth of the cottonseed-crushing industry in India. Perhaps the most important factor is the insistence of the Indian farmer on using the whole seed for feeding cattle and his reluctance to change over to cottonseed cake. Also, crude cottonseed oil as obtained in the Indian market has a dark reddish-black colour and disagreeable taste and odour, and thus cannot be used by consumers for edible purposes directly but has to be suitably processed. Even on refining by conventional methods the final product (oil) obtained is of dark colour compared to other edible vegetable oils and is not liked by the consumers. Hence, if cottonseed crushing is to increase, we have to see that the crude oil obtained on crushing cottonseed by Indian oil mills should be of such quality that on refining by conventional alkali method or some other cheap process it should yield a light-coloured oil similar to that obtained from groundnut or other seeds. It may be pointed out that the experience in other countries is that it is possible to do so. Large quantities of cottonseed oil are produced in America for manufacture of shortening, margarine and salad oil without any difficulty.

The yield and quality of cottonseed oil are greatly dependent on the extent and nature of the deterioration of the seed from which it is expressed. The deterioration occurs in the field due to weather conditions at the time of harvesting. In other cottonseed-producing countries like the U.S.A., great care is exercised to avoid field damage by good harvesting practice. Also, cottonseeds are a very perishable commodity and their handling and storage should be done with great care. When seeds are to be stored in large quantity and for a considerable period it is very necessary to build proper storage silos and bins with air-circulation arrangements, etc., to avoid damage due to overheating. The moist seed should be dried before storing and moisture should not be more than 10-11%. In our country, what contributes most towards the deterioration in quality of cottonseed oil is the long interval of time that passes at the ginning and oil mills after harvesting.

It is also very important that the seed before crushing should be cleaned, delinted, dehulled, cooked and flaked properly to get good-quality oil. Very little attention is paid by the oil millers in India to these items.

Cottonseed oil is rather unique among the various vegetable oils available for edible purposes. It has a dark reddish-black colour, which is mainly due to the presence of gossypol and allied pigments. These can be removed to a considerable extent by alkali treatment under carefully-selected conditions provided the oil quality has not been damaged previously by improper handling during harvesting, storage and crushing of the seed.

For the manufacture of vanaspati we have found it preferable to purchase washed cottonseed oil in preference to crude oil because when crude cottonseed oil is stored for long periods, the colour of the oil gets fixed. In fact it has been proved recently[1] that free gossypol in oil soon attacks glycerides and fatty acids forming gossypol fatty acid esters, which are not soluble in alkali, and so cannot be removed by conventional alkali refining. Hence it is preferable to purchase washed (once-refined) cottonseed oil from oil mills. For removing colour from washed cottonseed oil, the oil is once more treated with caustic lye. This step is often called re-refining and is carried out both by batch as well as continuous method. For the present, we will confine ourselves to the batch method which is followed in this country. The operation in the batch or kettle method may be classified further into the dry method or the wet method.

In the dry method, which is widely used in America a strong lye (15 to 40°Bé) of caustic soda is mixed with oil at a temperature of 25-35°C, while in Europe the wet method *i.e.*, neutralization of oil at a temperature of 80-90°C with weak lye (4-6°Bé) is widely practised. We have tried both these methods and have found the latter method to be more effective, as it leads to less refining loss. Details of the method followed by us and the colours at various stages after different treatments are described in this note.

Dry Method of Re-refining

16 tons of washed cottonseed oil were taken in a refining kettle, equipped with steam coils, stirrer, caustic lye and hot water spraying arrangement. The oil was deaerated for 15 minutes under vacuum to remove the air dissolved in the oil. After starting the stirrer at full speed (30 R.P.M.), 36 gallons of caustic lye of 40°Bé were sprayed into the oil with the help of a pump. The oil was at a temperature of 35°C. Stirring was continued for another 20 minutes after the addition of lye. Temperature was then raised to 125°F, slowing down the stirring progressively as the break occurred. About 30 gallons of hot water were sprayed to soften the hard particles of soap and help in agglomeration. Stirring was continued for another 5 minutes after the spraying of hot water. The soapstock was drained from the bottom of the kettle after settling for 4 hours. The oil was washed once with hot water without stirring or heating. Further water washes were carried out by raising the temperature of the oil to 90°C and slow stirring. After six water washes the oil was dried under vacuum.

Wet Method of Re-refining

16 tons of washed cottonseed oil were deaerated as above. The oil was then heated to 45°C and 150 gallons of caustic lye of 6°Bé were sprayed into the oil; stirring at full speed was continued after the addition of lye, and the temperature was then raised to 85°C. After stopping the stirrer, 150 gallons of hot water were sprayed. The soapstock was drained after settling for 5 hours. Water-washing and drying were carried out as usual.

Bleaching

After drying under vacuum the charge was bleached with 1% of Tonsil ACA bleaching clay and 0.15% Norit OLP New active carbon at 105°C for half-an-hour, cooled to 70°C and filtered.

Hydrogenation

Hydrogenation was carried out at 250°F for a period of five hours. Hydrogen pressure was controlled at 15 P.S.I.G. Nickel catalyst (reduced from nickel formate in a Wurster and Sanger reducer in the plant) was used.

The oil after hydrogenation was mixed with hydrogenated groundnut oil and processed normally for post-refining and deodorisation. Table I gives comparative readings for the dry and wet methods of neutralisation.

TABLE I

Comparative Readings for the Dry and Wet Methods of Neutralisation

Charge No.	Colour of washed oil Y+R	Method of Refining	Colour after alkali Treat. Y+R	Colour after Bleaching Y+R	Colour after Hydrogenation Y+R
1.	43+4.9	Dry	23+3.1	8.4+1.0	2.8+0.4
2.	42+4.9	Dry	23+3.1	9.2+0.9	2.6+0.5
3.	35+4.0	Dry	20+2.8	8.0+0.8	2.4+0.5
4.	35+4.8	Wet	20+2.3	7.0+0.6	2.6+0.3
5.	35+4.8	Wet	20+2.1	5.7+0.6	2.6+0.4
6.	36+3.6	Wet	20+2.2	5.1+0.5	2.4+0.3

All colour readings are in a 1-inch cell.

REFERENCE

1. L. C. Berardi and V. L. Frampton, J. Amer. Oil Chem. Soc., 1957, *34*, 399.

6. RE-REFINING OF COTTONSEED OIL BY CONTINUOUS REFINING PLANT FOR USE IN VANASPATI INDUSTRY

By

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The continuous re-refining of washed cottonseed oil on a De Laval Short-Mix Plant offers little advantage in colour reduction over the usual kettle practice. However the saving in oil is considerable. Phosphoric and citric acid treatment facilitate later washing and removal of soap. Higher temperatures do not affect colour reduction but reduce washing losses. Higher mixing speeds, lye concentration and contact time all give lighter-coloured oils. Neutralising either in a kettle or in a D.L.S.M. Plant does not affect the fluorescence if present in the oil.

The majority of vanaspati factories process washed cottonseed oil only, because the consumers of vanaspati are very sensitive to its colour and unless the refining plant for crude cottonseed oil is entirely isolated from the main plant it cannot be worked for fear of colour contamination from common pipelines, tanks, filter presses, etc. Also, freshly-crushed crude cottonseed oil is not available to many factories as they are situated far from the crushing centres.

Our experience with re-refining of cottonseed oil by kettle practice gave us refining losses varying between 1.25 and 1.50% on the weight of washed oil treated, depending on the original quality of the oil and the concentration of treating lye. The final colour of the bleached oils varied widely and the original colour of the washed oil did not give any indication of its bleachability or of the colour of the final product, even when the lye treatment and the bleaching materials used were identical. Washed oils which have been bleached and had lighter colours to begin with invariably gave deeper-coloured end-products.

Table I shows some of the many runs of cottonseed oil re-refining by kettle practice and after-treatment for the production of vanaspati. We have recently installed the neutralising step of a De Laval Short-Mix Plant in our factory. Experiments were conducted by us on full-scale runs through this plant for re-refining of washed cottonseed oil to find out the extent to which this equipment can minimise the re-refining losses, and the bleachability of oil neutralised through this plant. In our experiments we included pre-treatment of washed cottonseed oil with chemicals like sodium silicate, citric acid and phosphoric acid. This treatment was carried out at what is usually called "the degumming stage." The idea was to find out the effect of these chemicals on the cottonseed oil colour, whether they give rise to lighter-coloured bleached oils and better end-products, and also how much they help in the washing-out of soap from neutralised oil.

The Equipment

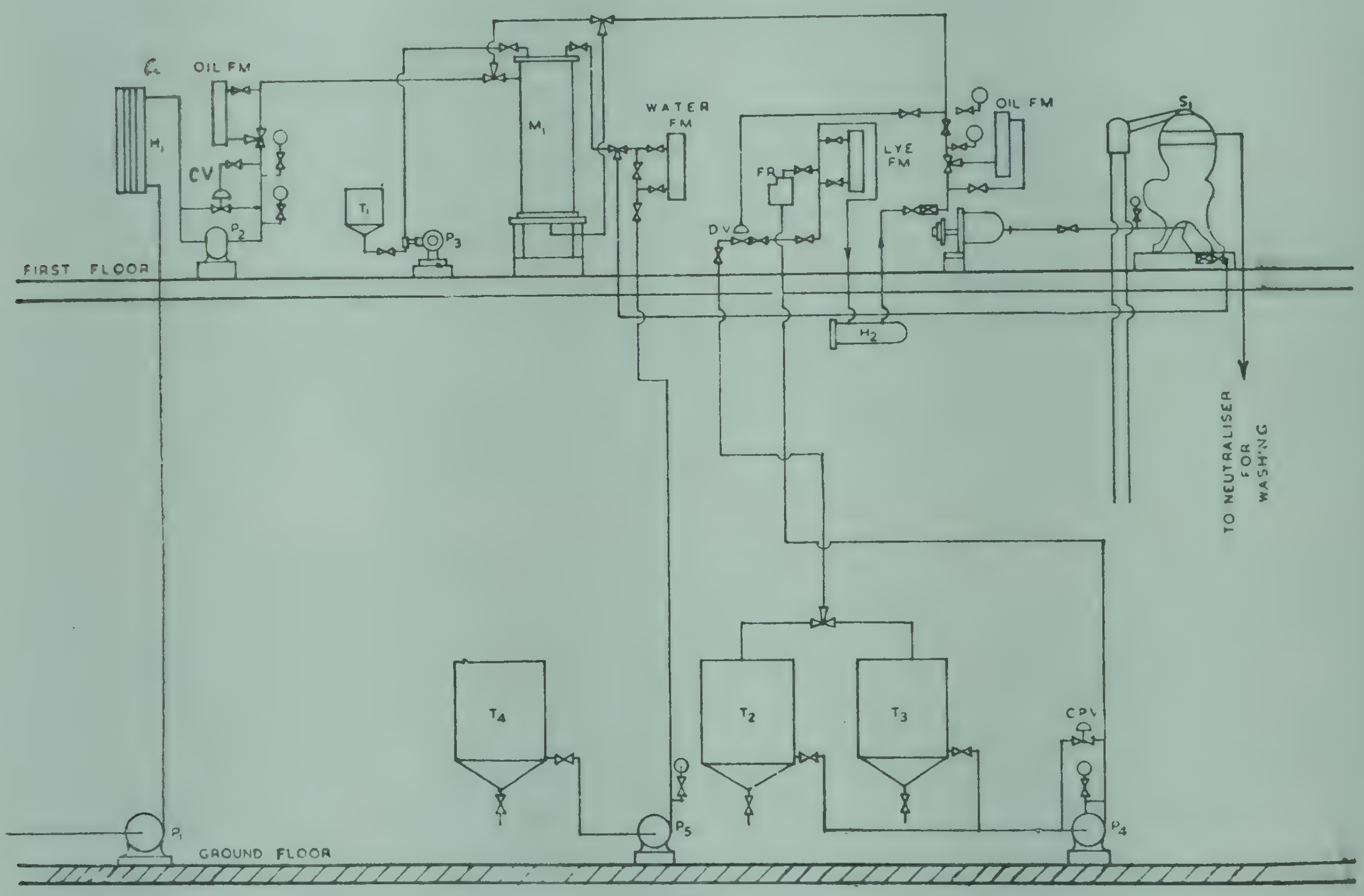
The flowsheet of the equipment installed at our factory for continuous neutralising is shown in Fig. 1. It consists of a centrifugal Pump P_1 for continuously feeding the plant

TABLE I

Kettle Re-refining of Washed Cottonseed Oil

Run No.	Washed oil colour in 0.25-inch cell (Y+10R)	F.F.A. of washed oil, %	Alkali treatment in usual type of open neutraliser of 13.5 tons working capacity	Loss on wt. of oil in neutralising, %	Bleach materials used on wt. of oil		Colour of bleached oil in 1-inch cell (Y+5R)	Colour of hydrogenated oil in 5.25-inch cell after post bleaching	Colour of deodorised hydrogenated oil with 5% added refined sesame oil, in 5.25-inch cell
					Tonsil ACA %	Zenith Active Carbon %			
142	15Y+1.8R (33)	0.30	Lye 40°Bé equivalent to that required for 1 % FFA, subsequent wash with soda ash solution wash	1.35	0.8	0.25	8.3Y+0.8R (12.3)	15Y+1.6R	15Y+1.7R
394	15Y+1.6R (31)	0.20	Lye 20°Bé with 10 % soda ash dissolved, added equivalent to that required for 1% F.F.A.	1.20	1.2	0.25	10Y+1.2R (16)	20Y+2.0R	20Y+1.9R
431	14Y+1.4R (28)	0.25	Same as Run No. 142, contact time 30 minutes.	1.45	1.2	0.25	14Y+2.0R (24)	25Y+2.8R	25Y+2.8R
784	15Y+1.3R (28)	0.30	Same as Run No. 394, contact time 45 minutes.	1.30	1.2	0.25	15Y+1.8R	20Y+2.6R	22Y+2.6R

from two oil-tanks each fitted with an oil-circulation device for mixing. The oil after analysis from any of these two tanks is fed by Pump P_1 to Steam-Heated Plate Heater H_1 placed on 1st floor. The plate heater is capable of heating the oil flowing through at any constant volume to any fixed temperature between 40°C to 110°C as its steam supply is through a self-adjusting steam-flow controller.



FLOW SHEET OF DELAVAL SHORT MIX NEUTRALISING STEP
DSML

FIG. 1

The oil after heating to any fixed temperature flows to another multi-stage centrifugal Pump P_2 which feeds the entire plant with heated oil rightly proportioned continuously at the desired pressure of about 3-5 kg/cm.^{2} once the seal in the Hermetic Separator is established. At the delivery line of this Pump P_2 is fitted the constant Oil Flow Controller, the flow-meter and the flow-recorder which enable the operator to maintain a constant flow of the heated oil. The normal operation is 2000 liters of oil per hour. The oil is next fed to the Paddle Mixer M_1 which gets a constant feed of any degumming chemical contained in Stainless Steel Tank T_1 by means of a Proportioning Plunger Type of Pump P_3. Water alone can also be proportioned into this mixer either from the proportioning pump or through a Service Water system described later. The mixer has a capacity of 560 lb. of oil and has a 3-speed stirring arrangement to suit various requirements. Oil can also be bypassed in case no degumming or chemical treatment of the oil is found necessary prior to lye treatment. The oil next meets the required dose of caustic lye and the lye and oil are mixed in a Knife Mixer M_2. The knife mixer has a capacity of about 1 kg. of oil and it consists of 14 knives revolving in a cylinder at speeds which can be regulated to 440, 685 or 1430 R.P.M. It is necessary to keep this mixer running at the right speed so that unnecessary emulsification of the oil/lye mixture is avoided for the correct working of the plant.

The lye dosing equipment consists of two Lye Tanks T_2 and T_3 placed on the ground floor, to feed the requisite quantity of the right strength of lye through Caustic Pump P_4. There is a Constant Pressure Valve C.P. fitted at the delivery line of this pump P_4 so that it feeds the lye to the oil at a fixed pressure of 9-12 kg/cm_2 irrespective of the quantity of the lye required in the system. The lye is fed to the system through a Flow Resistance Box FR, the Lye Flow Meter (which gives visual control of the lye) and the Differential Pressure Valve. By these appliances a pre-determined quantity of the lye of the desired strength can be maintained proportional to the oil flow irrespective of pressure variations in the system. The over capacity lye passes through Differential Pressure Valve DV back to the lye tanks. Steam Heater H_2 is provided to heat up the proportioned lye to any desired temperature upto 90°C before introducing it into the oil stream if required.

The oil/lye mixture is continuously fed to the De Laval Hermetic Centrifuge S_1 by a special Inlet Device at the bottom of the machine through its hollow spindle into its bowl fitted with separating discs at a pressure of 3-5 $kg/cm,^2$ and soapstock is separated from the body of the neutralised oil continuously. The oil is discharged through an enclosed outlet fitted with a sight glass and can be either led to the washing system or to the neutralisers for subsequent washing operations. As we have not installed the washing step, the oil is delivered to the neutralisers by its own pressure. The separator is provided with a 7.5 H.P. motor and the bowl revolutions are about 6,800 per minute at full load.

To facilitate the flow of soapstock out of the bowl and down the conveying pipes some amount of hot flushing water is necessary. This is supplied by means of Centrifugal Pump P_5 from a Constant Level Tank T_4 through a flow meter as shown in Fig. 1.

Details of eight experimental batches of washed cottonseed oil treated through the D.L.S.M. plant are given in Table II.

(a) Mixer M_1 has 195 R.P.M. at High speed, 95 R.P.M. at medium speed and 50 R.P.M. at low speed.

(b) Caustic lye in each case contained 10% of commercial sodium carbonate on the weight of caustic soda (solid).

(c) Mixer M_2 (oil/caustic lye Mixer) has 1430 R.P.M. at high speed, 685 at medium speed and 140 at low speed.

(d) Flushing water is fed at a temperature of between 85 and 90°C.

(e) Dehydration and bleaching was carried out in a vacuum bleacher at 95°C and the oil was cooled to 80°C before breaking the vacuum and filtration.

(f) Contact time of lye and oil when oil flow is 2000 litres/hr. is about 30 seconds and less when oil flow is higher. With kettle practice this time is about 45 minutes with 20°Bé lye and 25-30 minutes with 40°Bé lye.

(g) The lye was at a temperature of 80-85°C.

T

Details of Re-refin

	Washed cottonseed oil					Chemical treatment			Neutra		
Run No.	Quantity treated (tons)	Colour in 0.25 inch cell (Y+10R)	F.F.A. %	Input, 1./hr.	Temperature of oil, °C	Chemical used	% Dosed V/V	Mixer speed M I	Lye strength, °Bé.	Quantity dosed	Mixer speed MI
A	13.05	13Y+1.5R (28)	0.25	2000	65/70	16°Bé sodium silicate	0.25	High	30	Equal to 1% FFA in oil	High
B	13.44	13Y+1.3R (26)	0.30	2500	70/75	,,	0.12	Medium	20	,,	High
C*	12.84	19Y+1.6R (33)	0.2	2000	70/75	,,	0.50	Medium	30	20% less	Medium
D	14.50	14Y+1.4R (28)	0.30	2000	70/75	25% solution of citric acid	0.10	High	20	Equal to 1% FFA	High
E*	13.59	18Y+1.6R (34)	0.25	2000	70/75	,,	0.05	High	30	15% less	High
F	13.37	14Y+1.4R	0.20	2000	70/75	Comml. phosphoric acid (about 80-85% acid)	0.05	High	20	Equal to 1% FFA	High
X	13.44	15Y+1.5R (30)	0.35	2500	70/75	...	...	...	30	,,	High
Y	12.74	13Y+1.3R (26)	0.30	2000	80/85	...	...	...	20	,,	High

* Runs C and E:—Defective working of lye flowmeter.

II

Cottonseed Oil in DLSM Plant

	Washing					Bleaching					
Loss of oil in soapstock, %	% of sodium soap before wash	Number of washes	% of water on vol. of oil	% sodium soap after washing	Loss of oil in washing %	% of Tonsil ACA	% of Zenith Brand Active Carbon	Colour of Bld. Oil in 1-inch cell (Y+5R)	Colour of Hydrogenated Oil in 5.25-inch cell	Colour of post-bleached oil in 5.25-inch cell	Colour of deodorised oil in 5.25-inch cell with 5% sesame oil added
.75	0.18	2	25	0.05	0.30	1.2	0.25	15Y+1.5R (22.5)	25Y+2.5R	24Y+2.4R	25Y+2.4R
.68	0.20	2	25	0.04	0.30	,,	,,	18Y+1.8R (27)	30Y+2.8R	28Y+2.6R	28Y+2.7R
.72	0.19	2	25	0.05	0.25	,,	,,	20Y+2.0R (30)	30Y+2.8R	28Y+2.8R	25Y+2.7R
.62	0.16	2	20	0.02	0.25	,,	,,	18Y+1.8R (27)	30Y+2.8R	25Y+2.7R	25Y+2.7R
.68	0.15	2	20	0.02	0.20	,,	,,	20Y+1.9R (29.5)	30Y+3.0R	30Y+2.8R	28Y+2.8R
.70	0.14	2	25	0.01	0.20	,,	,,	17Y+1.7R (25.5)	30Y+2.6R	30Y+2.5R	28Y+2.5R
.68	0.20	3	40	0.04	0.40	,,	,,	17Y+1.7R (25.5)	30Y+2.5R	28Y+2.6R	30Y+2.5R
.72	0.18	3	40	0.05	0.35	,,	,,	20Y+2.0R (30)	30Y+2.7R	30Y+2.7R	28Y+2.6R

Conclusions

It has been found that the continuous re-refining of cottonseed oil offers but little advantage in the colour reduction of the oil treated as compared to usual kettle practice. However, the saving in oil is considerable.

Sodium silicate does have some colour-loosening effect but does not reduce the soap contents in neutralised oil and does not contribute to ease of removal of soap traces from oil during washing operations.

Both phosphoric acid as well as citric acid do not attack the colour, but reduce the soap content in the neutralised oil to a slight extent and facilitate washing and better removal of soap traces.

Higher temperatures of neutralising are not found advantageous for colour reduction although they do tend to reduce the washing losses.

A higher mixing speed of the Knife Mixer is an advantage and does affect the colour.

Lye concentration and contact time when increased give lighter-coloured oils.

Neutralising either by kettle or through the D.L.S.M. plant does not affect the flourescence if present in the oil. None of the chemicals referred to in this work seems to have any action on the bloom.

Acknowledgment

I offer my sincere thanks to the Management of M/s. Kusum Products, Ltd. for allowing me to conduct this work and to present this paper.

7. PROCESSING CONDITIONS FOR THE PRODUCTION OF WHITE HYDROGENATED PRODUCT FROM 'WASHED' COTTONSEED OIL

By

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The use of 25°Bé lye at 60°C for re-refining of washed cottonseed oils, and of 1.5-2.0% of a 10 : 1 earth-carbon mixture at 100°C for subsequent bleaching, is recommended. In order to yield a satisfactory, visually-white hydrogenated product of colour 0.3R (1-inch cell), the re-refined oil needs to have a colour less than 2.2R. Post-bleaching and deodorisation do not cause colour reduction.

Introduction

In the interest of the national economy and with a view to developing the utilisation of cottonseed in this country, the vanaspati industry has undertaken to utilise cottonseed oil in increasing quantities in the manufacture of vanaspati. The cottonseed oil now available to vanaspati factories is pre-refined or alkali-washed oil. The pre-alkali treatment is done by the crushing mills themselves. The F.F.A. of the oil is not high and varies between 0.12 and 0.3%, but the colour of the oil differs very widely from consignment to consignment. In the case of cottonseed oil the yellow of the oil gives no trouble in removal, but the red tint presents special problems. The colour-bodies of 'washed' cottonseed oil are very tenaciously held in the oil and in some cases they get fixed partially or wholly.

The quality of washed oil is closely related to the quality of the crude from which it has been produced, which in turn depends on the conditions under which the seed is produced and stored, the milling conditions (especially moisture, temperature and time of cooking), the temperature at which the oil is stored the equipment for crushing. The milling conditions are not scientifically controlled, the crushers in our country do not possess the proper equipment and there is a lack of scientific knowledge in respect of this oil; hence a great disparity is to be found in the quality of oil crushed from time to time by the milling units. The 'washed' cottonseed oil produced by them, therefore, also differs widely in quality. Since no trading rules on the basis of standards for colour and bleachability of washed oil have so far been developed and adopted, the suppliers recognise little responsibility in standardising or improving the product.

Table I shows how consignments of washed cottonseed oils obtained from the same centres of supply vary in colour from time to time. The red tints of these oils range from 3.0 to 17.6 in a 1-inch cell, though the free fatty acid content in most cases is almost the same. Because of this disparity in colour of different consignments, no hard and fast line of processing can be followed for all the consignments to yield a resultant hydrogenated product which will appear white to the eye and be acceptable to the market. The processing conditions have to be decided separately in each case depending upon the red tint.

TABLE I

Colour Readings, F.F.A. and Ref. Index of 'Washed' Cottonseed Oil Obtained from Various Centres in India

Consignment No.	Centre	Colour Lovibond (1-inch cell) Y	R	F.F.A. %	Ref. Index (B.R.) at 40°C
1.	Sirhind (E. Punjab)	25.0	3.0	0.12	57.5
2.	,, ...	30.0	4.0	0.21	57.5
1.	Patiala (E. Punjab)	40.0	5.8	0.11	57.2
2.	,, ...	40.7	5.4	0.21	57.1
1.	Khanna (E. Punjab)	30.0	3.0	0.14	57.1
2.	,, ...	29.0	4.0	0.20	57.5
3.	,, ...	40.0	8.0	0.21	57.2
4.	,, ...	42.0	5.0	0.18	57.1
5.	,, ...	40.0	4.2	0.15	56.8
6.	,, ...	49.0	8.2	0.21	57.2
7.	,, ...	57.0	12.2	0.28	57.0
1.	Sunam (E. Punjab)	30.0	4.0	0.21	57.2
1.	Ludhiana (E. Punjab)	40.0	6.5	0.18	57.2
1.	Amraoti	31.0	4.3	0.20	57.2
1.	Bombay	30.0	4.2	0.12	57.2
1.	Khangaon (Bombay)	30.0	5.2	0.14	57.2
2.	,, ...	40.0	8.0	0.25	57.2
1.	Kurdwadi	30.0	4.0	0.21	57.1
1.	Badnera (Madhya Bharat)	35.0	4.4	0.14	57.0
2.	,, ...	36.7	5.8	0.21	56.9
1.	Ujjain (Madhya Bharat)	50.0	17.6	0.31	57.2

Efforts made in this direction, to determine the most favourable conditions of processing and to know how the colour of the hydrogenated product is related to the colour of the re-refined oil and the colour of the washed oil from which it has been produced, are here reported. It has been pointed out by Bailey that despite frequent occurrences of objectionable colours in cottonseed oil, special refining procedures are not available for their removal. The only course in the refining of oils containing unusually high quantities of pigments, is the use of stronger lye, more bleaching clay or re-refining. This experience is true not only for crude but also for 'washed' cottonseed oil.

TABLE II

Effect of Concentration and Quantity of Lye in the Re-refining of 'Washed' Cottonseed Oil

(*All colours as Y, R on 1-inch cell*)

Sample No.	Colour of 'washed' oil	FFA %	Treatment					Lye added Vol. % of oil	Lye concentration and resulting oil colour					
			Lye stirred for, mins.	Stirrer speed, R.P.M.	Temp. °C	Second stage			15° Bé	20° Bé	25° Bé	30° Bé	35° Bé	40° Bé
						Stirred for, mins.	Temp. °C							
1.	40.0, 7.6	0.21	20	1200	40	Nil	Nil	1	35, 6.1	30, 6.0	30, 5.0	30, 6.0	30, 6.0	30, 6.4
	,,	,,	,,	,,	,,	10	60	1	35, 5.9	30, 5.8	30, 4.8	30, 5.9	30, 5.9	30, 6.0
	,,	,,	,,	,,	,,	Nil	Nil	2	32, 5.3	30, 4.6	30, 4.4	30, 4.7	30, 5.2	30, 5.4
	,,	,,	,,	,,	,,	10	60	2	31, 5.2	30, 4.4	32, 4.2	30, 4.5	30, 5.0	30, 5.1
	,,	,,	,,	,,	,,	Nil	Nil	3	32, 5.0	30, 4.4	30, 4.1	30, 4.1	30, 4.5	30, 4.7
	,,	,,	,,	,,	,,	10	60	3	30, 4.8	30, 4.2	30, 4.0	30, 4.0	30, 4.3	30, 4.3
	,,	,,	20	2000	,,	Nil	Nil	3	30, 4.6	30, 4.1	30, 4.1	30, 4.3	30, 4.3	30, 4.3
	,,	,,	,,	,,	60	Nil	Nil	3	30, 4.4	30, 4.0	30, 3.9	30, 3.9	30, 4.0	30, 4.0
2.	40, 9.5	0.21	20	1200	40	Nil	Nil	2	...	...	30, 6.8	...	...	...
	,,	,,	,,	,,	,,	10	60	2	...	...	30, 5.1	...	...	...
	,,	,,	30	,,	60	Nil	Nil	3	...		30, 4.8	...	...	...
3.	36, 4.9	0.20	20	1200	40	Nil	Nil	3	...	...	27, 2.5	28, 2.5	...	...
	,,	,,	,,	,,	,,	10	60	3	...	...	27. 2.4	28, 2.6	...	...
	,,	,,	,,	,,	,,	10	70	3	...	...	27, 2.4	28, 2.6	...	...
4.	40, 4.6	0.21	20	1200	40	Nil	Nil	3	...	...	27, 2.4		...	...
	,,	,,	,,	,,	,,	10	60	3	...	...	26, 2.3	...	...	...
	,,	,,	30	,,	60	Nil	Nil	4	...	...	20, 2.0	...	...	...
5.	30, 3.6	0.19	20	1200	40	Nil	Nil	3	...	21, 2.2	21, 2.1	25, 2.0	...	...
	,,	,,	,,	,,	,,	10	60	3	...	21, 2.2	20, 2.0	21, 2.0	...	...
	,,	,,	,,	,,	,,	10	70	3	...	21, 2.2	20, 2.0	23, 2.0	...	...

Though the free fatty acid content of 'washed' cottonseed oil is low, the amount of caustic lye generally added to other oils for neutralising the free fatty acid and removing the colour is ineffective for this oil. This quantity does not produce the required amount of soap necessary to absorb the coagulated colour bodies or to dissolve out the maximum of the pigments. The alkali therefore has to be used considerably in excess. Since the expression of this excess as a percentage of the theoretical quantity required is not rational at such low F.F.As., the caustic lye used has been given as a volume percentage of the oil treated.

Experimental

To investigate the effect of lye concentration, amount of lye and temperature on the removal of colour from washed cottonseed oil, experiments were carried out in the laboratory on 5 oil samples of varying colour readings (Table II). The first sample was subjected to all the varying conditions of refining, while the other samples were tried under conditions initially established as favourable. Caustic soda is usually added at a temperature of 40°C and the temperature is then raised to 60°C to separate the soapstock, hence these two temperatures have been used in these tests. Higher temperatures are not found suitable for cottonseed oils. The effect of increasing the speed of stirring on the removal of colour has also been studied in the case of the first sample.

It will be clear from Table II that neither weaker nor too high concentrations of caustic soda are favourable for reducing the colour of washed cottonseed oil, but the increase in the amount of caustic lye added is directly related to the reduction in colour in each case. Some of the methods when applied to full-scale plant operation were also corroborated. In plant-scale working, colour removal under the same conditions was found much higher than in the laboratory experiments.

Table III gives the optimum temperature of bleaching of re-refined cottonseed oil. These data relate to laboratory experiments on one particular sample of cottonseed oil re-refined in the factory. The bleaching was carried out in a beaker with mechanical stirring. The oil was heated to the required temperature, the bleaching material added and stirred in for 30 minutes.

TABLE III

Optimum Condition of Bleaching of Re-refining Cottonseed Oil

Sample No.	Colour of re-refined oil (1-inch cell) Y	R	Bleaching material used	Temp. of bleaching, °C	Colour of bleached oil (1-inch cell) Y	R
1	25.0,	2.2	1% Tonsil	90	8.7	0.9
			1% Tonsil	100	7.6	0.9
			1% Tonsil	110	7.6	1.0
			1% Tonsil-carbon mix, 10:1	100	6.6	0.9
			1.5% Tonsil	100	6.2	0.8
			1.5% Tonsil-carbon mix, 10:1	100	4.8	0.7
			1.5% Tonsil-carbon mix, 10:2	100	4.8	0.7
			2% Tonsil-carbon mix. 10:1	100	4.2	0.5

The results indicate that a temperature of 100°C is favourable to cottonseed bleaching and that increasing quantities of bleaching clay are proportionately more effective in the removal of the colour. The carbon-earth mixture is more effective in removing the red tint than the earth alone. When reproduced on the plant-scale, even better bleach colours were obtained, probably because of the use of vacuum, otherwise the results were in line with those obtained in the laboratory.

Further investigations were made on the plant-scale to relate the colour of the finished product obtained after hydrogenation to the re-refined colour. The colour of re-refined oil has a major bearing on the colour of the hydrogenated product, the effects of bleaching and hydrogenation on a particular oil being but limited. The efficiency of those operations depends on the nature of residual pigments. Fixed colours are difficult to bleach and hydrogenation is not able to substantially reduce them. It was found that washed oils of higher red tints have colouring matters which are more or less fixed.

For obtaining a white product, the re-refined colour has to be as low as possible and efforts have to be directed to achieve this end. It has been noticed that unless the colour of the washed oils is brought down to about 2.0 red in a 1-inch cell by the process of alkali treatment, it cannot be expected to yield a white product of acceptable quality. A product looks white to the eye if its tint is close to 3.0 Yellow and 0.3 Red in a 1-inch cell.

Table IV gives the data obtained on bleaching re-refined oils and their subsequent hydrogenation and post-bleaching and deodorisation, on 6 batches of the oil of varying tints. All these operations were carried out in 5-ton batches. All hardened samples were re-filtered in the laboratory with the addition of Hyflosupercel to clarify them further before testing for the tints.

TABLE IV

Effect of Bleaching and Hydrogenation on Re-refined Cottonseed Oils of Different Tints

(Colour on 1-inch cell)

Batch No.	Bleaching material used, %	Re-refined oil		Bleached oil		Hydrogenated oil		Post-bleached oil		Deodorised oil	
		Y	R	Y	R	Y	R	Y	R	Y	R
1.	1% Tonsil-carbon mix, 10:1	25.0	2.2	3.4	0.5	2.7	0.3	2.7	0.3	2.7	0.3
2.	do	24.0	2.2	4.3	0.5	3.0	0.3	3.0	0.3	3.0	0.3
3.	do	29.0	2.4	7.3	0.9	4.4	0.7	4.4	0.7	4.4	0.7
4.	1.5% Tonsil-carbon mix, 10:1	30.0	3.0	10.0	1.2	6.6	1.1	6.5	1.0	6.5	1.0
5.	do	27.0	3.4	11.0	1.2	6.0	0.8	6.0	0.8	6.0	0.8
6.	2% Tonsil-carbon mix, 10:1	30.0	4.4	13.0	1.4	5.4	0.8	5.4	0.8	..	...

The overall loss of fat during all the stages of processing of washed cottonseed oil was estimated to range between 2.1 and 3.1%.

Discussion of Results

All the work reported was carried out on washed oils obtained from different producing centres, as noted in Table I. The colour of the oil, which is the most important factor in evaluating its quality, obtained from these centres from time to time differs so widely in the red tint, that the methods of treatment have to be adjusted each time.

On re-refining this washed oil by alkali treatment, increasing quantities of caustic soda lead to increased colour removal especially of the red colour component of the oil. The optimum lye concentration for effective removal of colour is 25° Bé. Lyes of lower strength take out less colour and a higher concentration of lye has the effect of colour reversion. The optimum temperature of re-refining is 60°C. Increase in temperature to 70°C has no further effect on colour reduction.

For bleaching re-refined oils, 100°C is a favourable temperature and about 1.5 - 2.0% of a 10:1 earth-carbon mixture is as effective as a 10:2 earth-carbon mixture. Earth alone is not as effective as the combination.

In bleaching and hydrogenating re-refined oil, if the residual tint is higher than 2.2 Red, the colour of the hydrogenated oil turns out much above the visual white of 0.3 Red. Hydrogenation does not always remove the same percentage of colouring matter from different oils, and depends on the degree of colour fixation of the oil. The process of post-bleaching and deodorisation have no effect on the reduction of colour. Only in one solitary case was a slight reduction in post-bleaching observed.

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DISCUSSIONS

Discussion Leader: Shri C. R. DAS,
(D.C.M. Chemical Works, Delhi)

General

C. R. Das. Steps for good refining, in the case of cottonseed oil, have to be taken right from the period of harvesting. If the seed is damaged at this stage by bad weather conditions or other causes, no amount of refining can produce a light-coloured refined oil. In countries such as the U.S.A., great care is exercised to avoid damage either in the field or during storage of the seed at the oil mills. The seed after ginning is shipped to the oil mills where it is stored in seed-houses provided with good air-circulation, so that at no point in the seed-house does the temperature go beyond 80°F. If this does happen, such seed is processed immediately.

Another factor which affects the quality of oil is the duration or period that occurs from the time seed is taken out of the seed-house to that when the oil is refined. Heat, sunlight and humidity are all factors which cause deterioration of oil in regard to colour, both at the stage of seed and after extraction. If this period can be reduced, an oil of good colour can be produced. Keeping other processing conditions constant, the quality of oil produced is almost proportional to this period. In one plant in the U.S.A., hardly 16 hours elapse between the seed stage and the refined oil stage, and very pale-coloured refined oil is obtained by thus avoiding all hold-ups.

Of course, this period is only one of the factors which influence the colour of oil. Conditions adopted at cooking, a few of which were described under processing, are also important. For refining crude oil, the kettle method is not the most suitable process. Continuous refining is much better; it not only reduces refining loss but definitely yields a much lighter product. Among continuous refining methods, miscella refining or liquid-extraction are superior.

Regarding the A.O.C.S. Method for determining refining loss, it has been found that in actual practice the refining loss is much less than by this method, and it is often stated that so much has been saved over this cup loss. This does not sound well. Laboratory conditions are generally considered to be ideal, and plant performance is always slightly lower. In this case, plant performance is better than that in the laboratory test. While agreeing that for comparison the method is of tremendous value, it is desirable that research scientists devise some other method of determining refining loss in the laboratory which will not show so great a disparity with the actual performance.

K. T. Achaya. I would like to analyse some of the fundamentals of refining and gossypol fixation in order to help the subsequent discussions.

It is now well established that all the titrable acidity in an oil is not due to F.F.A. Some 10-25% is caused by phosphatides sensitive to and hydrolysed by even the very dilute alkali used in the acid value determination. Also, it has been shown that while oil is *entrained* in the soapstock (during the refining procedure) as it begins to settle, it is only *saponified* during the next few hours after settling. Hence, quick removal of soapstock, as is done in the continuous refining procedure, will conduce to a low refining loss. Finally it is known that even if exactly the theoretical quantity of lye is used, the refining loss increases with time of contact, perhaps by occulsion of oil on soap. In brief, refining loss is caused by (i) F.F.A. removal as soap, (ii) phosphatide hydrolysis and removal by saponification and also by hydration and subsequent insolubilisation, (iii) entrainment and later saponification of neutral oil, (iv) occulsion of oil by soap or lye, (v) removal of mechanically-suspended impurities, and (vi) mechanical losses.

If stronger lye is used, contact is poor, and if contact is increased a certain degree of saponification is inevitable. If very weak lye is used, colour removal is poor. It would therefore appear rational to give a wash with very weak lye merely to remove free fatty acids and then to refine and agitate with stronger lye mainly to remove colour bodies and minimising oil losses caused by the presence of soap. The effect of showering with water under controlled conditions has yet to be established. It is possible that if this is done immediately after refining in a controlled way, neutral oil will be released and the refining loss will be lowered. It may also be found convenient to introduce water, and also perhaps brine as emulsion-breaker, from below into soapstock as it is settling.

In India especially, owing to storage practices which have been considered in another section in this Symposium, gossypol fixation is closely linked with refining practice. Gossypol is known to be fixed in several ways during seed storage; it can be bound to protein which may then be rendered somewhat oil-soluble. After release as crude oil gossypol may also be fixed by ester-interchange with fatty acids in the form of mixed glycerides. Finally both in seed and in crude oil storage, gossypol may be degraded to various pigments some known to contain adjacent diketo, quinone-like groups. The data on refining reported in our paper provide good support to some of these theories, and are listed below:

(i) The excellent effect of double-refining, where no F.F.A. is present in the second stage, is perhaps due to preferential removal of gossypol-containing glycerides, with about 3% refining loss.

(ii) Stronger lyes have comparatively greater effect on the refined oil colour of colour-fixed and high-acid oils than they have on fresh, low-acid oils, but the degree of bleachability in the former case is always less. Gossypol-glycerides are likely to be soluble in strong alkali.

(iii) On storage of oils, less yellow pigment is removed by earth and carbon bleaching, perhaps because it has entered into organic combination as glycerides.

(iv) The good effect of alcohol, with a corresponding increase in refining losses, may be due to the solubility of gossypol-glycerides in alcohol caused by the presence of the alcohol-soluble pigment.

Finally, it has been shown in work from the U.S.A., and recently from Delhi, that borax is able to form a complex with gossypol, and that the latter can be removed in this form. This interesting approach can perhaps be further extended to other, perhaps even cheaper, chelating and binding compounds. Gossypol besides possessing adjacent hydroxyl groups also functions as an aldehyde, and as an acid.

Also, colour reversion in cottonseed oil is a misnomer, and really means colour fixation.

J. G. Kane: (communicated). 1. All the laboratory data given in some of the papers are not likely to be applicable on a plant scale; perhaps less extensive pilot-plant data may have more practical value.

2. Values for F.F.A. of refined and bleached oils are missing.

3. Are F.F.A. and refining loss determinations so accurate that they can be expressed to two places of decimals?

PAPER 1

Being a review paper, there was no discussion.

PAPER 2

K. T. Achaya. A general feeling exists that there is an optimum lye excess. No rule of thumb can be laid down, since the work reported (item 3) in the paper shows that while for a low-acid, non-colour-fixed oil, an excess of lye or stronger lye will reduce colour markedly without affecting refining loss, for a colour-fixed oil, the refining loss rises considerably and colour is not correspondingly improved. Attention is also drawn to Table XII and Figure 1, from which it is seen that as the F.F.A. increases, the gap between refined oil colour and bleached oil colour narrows, and at an F.F.A. level of about 9 or 10, a refined oil will not tend to bleach at all. Another interesting effect found is the use of alcohol in greatly reducing colour (Table XI); of course these are only laboratory trials and cost and technical data on this use of alcohol have not yet been considered.

G. S. Sidhu. Has any new approach been made to the removal of gossypol apart from alkali-refining? Based on the structure of gossypol, it would seem possible to remove it by other means without affecting the quality of the oil.

B. S. K. Shastry. It has been found that a short interval after the first refining leads to an improved colour on re-refining, perhaps because the fine soap particles are able to settle down. Since light bleaches oil, it may be possible to employ U.V. light for the purpose. using tanks with glass roofs.

S. Zainul Abideen. Perhaps the use of alcohol at the bleaching stage rather than the refining stage may be helpful. The use of lime as an additive is worth considering. Why is the rise in peroxide value higher in bleached oil than in refined oil? Considering all the difficulties and expense, it hardly seems worthwhile to attempt to use cottonseed oil, but stick to groundnut.

M. Narayana Rao. The antioxidant effect of gossypol seems remarkable.

G. V. Sirur. It is noticed that the F.F.A. of oil extracted with alcohol is always low; is it possible to use alcohol for de-acidification in place of caustic, and what would be the economics?

J. S. Aggarwal. Comparable work at the National Chemical Laboratory of India, Poona, on the cost of extraction of neem oil shows that in two alcohol extractions, the acidity of the oil is halved, and the cost is about Rs. 2/- per maund (37 kg. or 82 lb.).

K. S. Murti. Removal of gossypol using *p*-aminobenzoic acid has been tried in America. In our laboratory experiments, gossypol was found to be largely removed, but on later refining, the final refined oil was not much better in colour than straight alkali-refined oil.

N. Bhojraj Naidu. Extraction with 70% alcohol results in removal of the colour and toxic material, and perhaps also the fluorescence.

C. R. Das. Regarding bleaching by light, some experiments in the U.S.A., have shown that any bleaching obtained only occurs in the first 2-3 hours. Any new additives could perhaps best be added not at the refining stage, but at the cooking stage, so as to improve the meal; *p*-aminobenzoic acid was effective but expensive. In a pilot-plant in Brazil using a mixture of aliphatic alcohols in a kind of continuous extraction, de-acidification and extraction are effected in one stage, and the oil is so light in colour that it is not even bleached.

R. K. Bhatnagar. The use of borax, along with other chemicals or in the form of its derivatives, goes as far back as 1928, but it was only recently, as a result of Dr. T. R. Seshadri's investigations, that interest in borax was revived. The salient features of the process developed and patented by him lay in the particular way that borax is used to remove gums and gossypol, prior to caustic refining. The process calls for rigid controls over the reaction conditions, and the refined oil obtained is free from gossypol and related compounds. The oil also does not show any fluorescence.

K. T. Achaya: (replying): 1. As already stated earlier, new approaches, including the use of borax, are being tried for removal of gossypol, which can function as an aldehyde, a base or an acid.

2. Regarding the beneficial effect of an interval after refining, it has been found (Table V) that long storage in glass beakers does lead to colour reduction, perhaps by light bleaching. This technique is usually used commercially only for oils like palm and castor for use in soap or non-edible purposes, but not for edible oils owing to the adverse effect on glycerides.

3. Alcohol has only been tried during the refining stage.

4. The conjugation induced by the bleaching procedure should also be borne in mind in considering the rapid increase in peroxide value of bleached oils.

5. Gossypol is a proven antioxidant, known to contribute to the marked stability of crude cottonseed oil. Crude oil, on keeping, hardly rises in acidity; rise in acidity in the oil while in seed is due to enzyme action, no gossypol being present in solution in fat but as a separate pigment gland.

PAPERS 3 & 4 (taken together)

B. Zachariassen. Degumming is worthwhile even in a solvent-extraction plant, since the gums can be mixed back with the cake increasing its food value. In most of the papers presented, the refining loss seems rather high, probably because a long contact time has been allowed. In the De Laval continuous plant, the lye is mixed with the oil using a knife mixer allowing a short contact time. In the laboratory a continuous refining trial with crude cottonseed oil from Modi Vanaspati Ltd., was made. An oil of F.F.A. 3.2, phosphatide content 0.9% and Wesson loss 4.8% was water-degummed and neutralised and re-refined with 24°Bé lye; the total loss was 6.0% (6.2% without degumming), the refined colour 70Y + 12-14R and the bleached oil colour 35Y+4-5R on a 6-inch (153 mm.) cell. When refining groundnut oil, the losses are mainly due to saponification and emulsification; as the quantity of lye is increased, the former increases and the latter decreases, and the total minimum loss in a continuous plant is reached at a lye excess of about 30% which probably also applies for cottonseed oil.

P. N. Mathur. No mention has been made in the papers of the F.F.A. after refining and re-refining, or of the nature and amount of bleaching earth used. Has this refining loss been calculated on the basis of oil obtained, *i.e.*, as dead loss, or has the oil entrained in soapstock also been considered?

In my experience, degumming always reduces the refining loss, sometimes to the extent of 2%, and is essential. Also, the dry method is followed, since it always gives a lower refining loss than the wet method.

M. Narayana Rao. In all the work reported, Lovibond Tintometers have been used for colour determinations, but are subject to a personal factor. The Spectrophotometer method has been suggested, but is rather expensive. In our experience, a Klett-Summerson Colorimeter gives good results, using a No. 42 filter for the yellow colour, a No. 54 or 56 for red, and No. 66 for blue.

S. Mazumdar. It may be pointed out that in Shri Mathur's paper, true continuous refining has not been done, but a part of the process, *viz.*, the refining stage, has been continuous. In the first degumming stage, over which there has been some discussion, there is bound to be some loss of neutral oil, but the total loss of degumming plus refining may be less than for straight refining. Degumming as used in the papers reported is not the same thing as gum conditioning, in which citric or oxalic acid is added to change the surface condition and render the gums insoluble in oil. Separation of gums depends on their economic value. For soya bean oil gum separation is recommended, but for cottonseed oil this step would merely increase the oil loss, and it is recommended that conditioned gums be carried over and separated later with soapstock. Regarding mixing, the shortest mixing time of alkali is generally believed to be the best, but in actual practice, there is an optimum for each oil, and too short a time may even lead to troubles like emulsification.

J. M. Shah. There is a discrepancy in Table IV of the paper, where the third, fourth, and fifth samples are actually shown to have higher bleached colours than refined colours. What are the relative merits of 'washing' crude oil with active carbon or with alkali? Often in the former case the oil is found to refine with difficulty subsequently.

K. G. Mathur. No paper has considered the question of fluorescence in cottonseed oil which carries over into the hydrogenated product, and leads to suspicion of adulteration with mineral oil; use of even 2-3% cottonseed oil in vanaspati leads to this fluorescence, which should be studied by research workers.

B. M. Jindal. The dry refining method is stated in one paper to yield a lower, and in another a higher, refining loss than the wet method. Similarly the degumming results are contradictory. Is the optimum excess of 200% lye given in the paper suitable for oil from all types of seed? The high speed at which losses are stated to be less has not been specified.

V. K. Parikh. It is rather difficult to compare the data in Table II since residual F.F.As. are not given.

B. Zachariassen. Referring to Table VII, what does the term 'centrifugation' imply and what quantity of oil was treated?

K. S. Murti (replying): 1. The A.O.C.S. refining method is the best available for comparative studies and was used throughout, and modified only where necessary to vary experimental conditions. Cup refining losses are employed in the U.S.A. as guides to refining; plant losses when continuous or semi-continuous refining is done are said to be less than cup losses, while batch methods are generally known to give higher refining losses.

2. The total of degumming loss plus refining loss was found to be higher than that in straight alkali refining. No centrifugal unit was used to separate the gums. In fact, in the second paper, degumming and refining was actually found to give better results than straight refining, and no doubt degumming has come to stay.

3. The F.F.A. of refined oils usually varied from 0.05-0.1%, and that of re-refined oils from 0.02-0.05%. They were not given because the tables were already too cumbersome.

4. For bleaching, 4% of earth, mostly Tonsil plus 0.4% carbon was used, as this is considered to be equivalent to 6% official A.O.C.S. earth. The carbon used was mostly Darco.

5. The conflicting results with the wet and dry refining methods as applied to crude oils may be due to differences in the meaning of these terms: in the work reported, the American techniques were followed, but the practices in Europe and India may be different. As also stated by Shri Mathur, dry refining had been found superior to wet. Shri C. R. Das has applied these terms to refining washed oils also.

6. While agreeing that spectrophotometric determinations of colour are desirable, the Lovibond Tintometer has been used so that the results can be of use to industry, which is familiar with such colour readings.

7. In the method used, where degumming was followed by settling and subsequent refining, the total refining loss was found higher than for straight refining. Centrifugation was of course very valuable for phosphatide recovery, and is advocated for cottonseed oil, which contains 2% of phosphatides (of which 55-80% can be recovered) since in advanced countries such recovery is done even from oils containing much less phosphatides, like wheat germ, rape, mustard, etc.

8. Regarding wet and dry methods of refining, it was sometimes found in the wet method that the break did not occur, hence more alkali was added.

9. Fluorescence did indeed occur, and needs to be studied.

10. Regarding the comment about the two speeds of agitation used, this is as specified by the A.O.C.S. Method, and was also applied in the pilot-plant runs in order to obtain comparable results.

11. There does not seem much point in comparing the refining losses at equal alkali excesses, since the object of the work is to find optimum refining conditions. There is no ready formula for refining any oil, least of all cottonseed oil.

12. Generally 20°Bé lye was found good for re-refining, but if the oil quality is good, even 18° or 16°Bé may suffice.

13. The term 'washed oil' is peculiar to India; when a crude oil is treated with active carbon in order to achieve the colour standard laid down for such washed oil, the temperature is often raised during which the colour gets fixed making subsequent refining difficult.

14. In answer to Shri T. V. Subba Rao, the sample numbers in the paper correspond to the same seeds as in the earlier paper on composition.

PAPER 5

P. N. Mathur. No data are given to support the arguments; the loss by the dry method is generally *less* than that by the wet method, not more as stated. The temperature of 85°C is excessive, generally 65° is not exceeded as the colour is affected. The melting point of the fat after 5 hours, the catalyst used and its percentage may also be given.

Rajeshwar Prasad. Apparently the batches of oil used for the two runs were different; hence comparisons are not justified, and it cannot be reasonably concluded that the wet method is more effective than the dry.

K. G. Mathur. What is the time of hydrogenation?

G. V. Sirur. Refining losses should be related to Wesson losses, which include phosphatides also, and should always be given in scientific work. Final colour and refining loss should both be considered, since it is no use having a low refining loss and a high colour.

K. S. Murti. The Wesson loss is time-consuming, and can often be predicted from F.F.A. content, though deviations of 1-2% do occur.

T. V. Subba Rao. Even if lengthy, it is necessary to systematically determine Wesson losses now, when the foundations for the industry are being laid, since later it is difficult to go back.

S. Mazumdar. An oil can have a low F.F.A. but still give a high Wesson loss. An alternative method to the A.O.C.S. Method is the recent chromatographic procedure for determining absolute loss.

S. A. Saletore. The dry method of refining is followed in America and the wet method in Europe owing to local conditions, which should also be considered in this connection in India.

K. G. Mathur. In factories the method described in Bailey's monograph on cottonseed is followed closely.

G. V. Sirur. Sometimes the wet method gives better results, and sometimes the dry, and only a laboratory trial will determine the method to be used. It depends on many factors like the type of seed, region of origin, etc.

J. G. Kane (communicated). Data on refining losses and soapstock composition are missing.

C. R. Das (replying): 1. The catalyst was 0.1% nickel on the weight of oil, and the melting point of the product 37°C.

2. Dry and wet methods have different connotations in the U.S.A. and Europe.

3. The re-refining loss when 6°Bé lye was used is about 2.2-2.5%.

4. It is difficult to use the same batch of oil in a factory, since new lots are added to the same tank. However since the red colour component of all the oils used is almost the same, they are likely to be comparable.

5. It is indeed desirable to state Wesson losses.

PAPER 6

K. G. Mathur. The data presented in the paper are only four runs chosen out of very many to summarise the overall findings. Also, for various reasons, complete continuous refining though undoubtedly desirable had not been installed in the plant; only continuous neutralisation has been discussed.

S. Mazumdar. The trend in cottonseed refining, as in all chemical operations, is towards continuous processes, and over 200 Sharples plants are in operation the world over. A fully-continuous plant for cottonseed oil should, in our opinion, have (i) a gum-conditioning stage, in which gums are not separated but carried over, (ii) a neutralising stage, in which neutral oil saponification is avoided by using only stoichiometric amounts of lye, (iii) a re-refining stage, designed to give a sharp break resulting in marked colour improvement with very little soapstock, (iv) centrifugal water washing in two stages, and finally (v) vacuum drying. The process is called, with absolute accuracy. the low-loss process, and will be judged by simplicity, cost and efficiency.

B. Zachariassen. The De Laval system uses 2, 3 and 4 steps, with an equal number of separators, according to the oil being used, *e.g.*, two steps for groundnut oil and three for cottonseed oil. Degumming to render the gums insoluble is done with phosphoric acid, especially for groundnut oil. At the special request of Indian refiners, a cheap one-step unit has also been designed; though essentially for neutralization, it is a multipurpose unit capable of being used for other stages also. It can also be installed in a batch refinery where it can be used in conjunction with existing equipment. For re-refining a special design of the hermetic separator is made. The rated capacity of the hermetic separator is 45 tons a day, but there is no limit to the possible size of the De Laval machine, the biggest present machine having a capacity of 120 tons a day. When oil and soap are separated the boundary level between these two components in the rotating separator bowl has to be placed close to the periphery to get the best result. In the hermetic separator this adjustment is simply made on an outlet valve without stopping the machine, and by adjusting this valve the maximum separating efficiency can be obtained enabling lowest refining losses with cleanest possible oil.

C. R. Das. Both De Laval and Sharples systems have advantages and disadvantages; in addition to these, two more continuous systems are coming into the picture. One is the Westphalia, another the Podbelniak contactor, so far only available in the U.S.A., which is a new and much cheaper system.

B. P. Maheswari. The paper under discussion has not made clear the history of the washed oil used. Also, the colour expected by refining washed oil is nowhere specified.

S. Mazumdar. Shri Mathur has reduced the refining loss, but the colour is not improved. Refining in two stages would greatly improve the colour without increase in refining loss. Use of an automatic proportionometer for addition of lye to oil would also help.

G. V. Sirur. The term 'washed oil' is one of the results of an unfortunate malpractice which has crept into the Indian industry. Some crushers give the crude oil a light alkali wash to reduce the colour to about 60-65, and then an activated earth treatment to further reduce it to the accepted specification value of 35. Thus the later refining loss is reduced, but vanaspati manufacturers are unable to bleach the oil. Actually the refining loss has been reduced at the cost of bleachability.

J. G. Kane (communicated). The actual saving of oil under different working conditions would be very instructive.

K. G. Mathur (replying). An oil with a higher red colour component is preferable to one lightly-bleached to a lower colour but also colour-fixed, in fact an unbleached oil is preferable to a badly-bleached one. A proportionometer had indeed been used in the system.

PAPER 7

Rajeshwar Prasad. This paper gives a ready-cut formula for re-refining by prescribing a colour of 2R in a 1-inch cell as the limit of the red component which has to be achieved in order that the subsequent processes of bleaching and hydrogenation may yield a product which appears white and acceptable to the eye.

Vanaspati prepared from groundnut oil has a tint of 1.5Y and 0.2R; the product starting from a re-refined cottonseed oil of colour 2R has a tint of 2.5Y + 0.3R. Such a cottonseed product can be mixed with a groundnut product to an extent of 10% or even more, but if the red component of the hydrogenated product exceeds 0.3R, it is difficult to utilise it to any great extent.

The above colour should also be a guide to the producers of cottonseed oil in preascertaining the quality suitable for the manufacture of vanaspati.

The marked drop in refrative index from a butyro-refractometer reading of 60 to one of 57.5 noticed on refining crude cottonseed oil may be verified; Indian Standard Specifications give the same value for both crude and refined oils.

K. S. Murti. In measuring Lovibond colour, the practice in America is to fix the yellow value and adjust and measure the red, while in India both are varied for a correct match. The U.S.A. procedure deserves consideration.

C. R. Das. This could be tried out by industry in actual use, and perhaps finalised at a meeting sometime later.

K. G. Mathur. Lovibond glasses become erratic in time.

C. R. Das. It is desirable to change them every two years, and to test colour independently in the quality-control department and in the plant.

G. V. Sirur. It is desirable to standardise oil, not on the basis of colour of washed oil (35 for Y + 10R) as in the present Indian Standard Specification, but on a basis of bleachability also, and some understanding on this by producers is very much needed.

C. R. Das. A paper on this appears in a later section.

SECTION V

HYDROGENATION OF COTTONSEED OIL

Discussion Leader: Dr. J. S. AGGARWAL,
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1. HYDROGENATION OF COTTONSEED OIL

By

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Cottonseed oil can be hydrogenated for the production of vanaspati and shortening by using a nickel catalyst which promotes selective hydrogenation. A nickel catalyst supported on a neutral carrier is preferable to unsupported one, in regard to rate and selectivity of hydrogenation and consistency of the product. From a mixture of cottonseed and groundnut oils, a product of good selectivity can be obtained if the hydrogenation is performed under the most suitable conditions.

Introduction

Cottonseed oil and its hydrogenated products in various forms are the main edible fatty materials consumed in the U.S.A. Since extraction of this oil is gradually increasing in India and Government has desired that about 10 per cent of cottonseed oil should be added to groundnut oil for the preparation of vanaspati it has been considered imperative to study the course of hydrogenation of this oil and compare it with those of other common oils.

The hydrogenation of oil to a low iodine value to yield hard oil or stearin is the simplest of hardening operations in that the factors of selectivity and *iso*-oleic acid formation are not involved. Optimum selectivity increases in different hydrogenated food products in the order: ordinary shortening, high stability shortening or frying fats, margarine oils. The characteristics for vanaspati are very similar to those of margarine oils. It should be relatively firm at low temperatures but must be free of glycerides which will not melt at the temperature of the mouth. The hydrogenation should be sufficiently selective, so that with the same drop in iodine value only a small amount of linoleic acid will remain ensuring the stability-characteristics to the product.

For studying the course of hydrogenation of cottonseed and some other oils the nickel catalyst was prepared as follows:

Nickel formate (58 g.) and refined groundnut oil (232 g.) were taken in a 3-necked 500 c.c. round-bottomed flask equipped with a mercury-sealed glass stirrer. A slow stream of hydrogen gas was bubbled through the oil-nickel formate mixture. The contents of the flask were heated to 150°C when the initial reaction began. The temperature was kept at about 190°C until this preliminary activity in the reduction is completed and the moisture driven off. The temperature was then raised to 230°C to 240°C and maintained at that level for 2-3 hours when the entire charge in the flask became jet black and no green particles were visible. The heat was turned off but the agitation and the introduction of hydrogen was continued during the cooling operation. When the temperature came down to 100°C, the excess of oil from oil-nickel catalyst mixture was separated by filtration so that the concentration of nickel in the congealed catalyst mass was about 25 per cent.

The hydrogenation of refined cottonseed oil (500 g.) was conducted in a laboratory Parr medium-pressure apparatus in which the temperature and pressure could be controlled. The speed of agitation was maintained at 525-550 R.P.M. The amount of catalyst added was 4 g. containing one gram of the metal, equivalent to 0.2 per cent nickel on the weight of the oil. Hyflo-supercel (2 g.) was also added. The temperature and pressure of hydrogenation were 176-182°C and 85-90 P.S.C. The purity of hydrogen was 99.97 per cent. Hydrogenation was continued till the product gave a slip point of 36-37°C. At this stage about 5 g. decolourising carbon and 5 g. hyflo-supercel were added and the hydrogenated oil was separated by filtration through a No. 1 Whatman filter paper.

The hydrogenation of another batch of the oil was carried out by using 75 per cent of the above used catalyst and 25 per cent of fresh material under similar conditions. Such experiments were repeated till four charges of the hydrogenated products were obtained with this oil. Similar hydrogenation experiments were also carried out with groundnut oil. With refined linseed and mustard oils experiments were undertaken only with fresh catalysts. In the case of mustard oil it was not possible to carry out the hydrogenation to completion. It was, however, found that if after conducting the hydrogenation for about one hour the poisoned catalyst was removed from the oil by filtration and then the fresh catalyst introduced into the filtered oil, the hydrogenation proceeded smoothly to completion.

The following characteristics of the products were determined.

The hydrogenation time was taken as the period from the start of hydrogenation till a slip point of 36-37°C was attained by the fat. The congeal point was determined by the method described by Bailey.[1] The consistency of the fat at 15°C was measured by the standard penetrometer IP 50/48 designed for lubricating greases. The butyro-refractometer (B.R.) reading at 40°C were also recorded. The iodine value (Wijs) of the fat and titre tests of the fatty acids were found out by A.O.C.S. Official Method Cd 1-25 and Cc 12-41 respectively. The saturated and *iso*-oleic acids in the total fatty acids were determined by the method of Cocks, Christian and Harding,[2] and the spectroscopic method[3] was employed for the estimation of linoleic acid. The amounts in per cent of the above acids when subtracted from 100 gave the quantity of oleic acid.

The data collected in hydrogenation of cottonseed, groundnut, linseed and mustard oils are given in Table I.

These results show that as raw cottonseed oil contains almost twice the amount of linoleic acid as groundnut oil, a high selective hydrogenation is necessary to reduce this acid to the minimum in the vanaspati prepared from cottonseed oil. In bringing them to the same melting point, the iodine value of hydrogenated cottonseed oil has remained somewhat higher than the product prepared from groundnut oil. The re-usage of the catalyst to a limited extent does not materially affect the selectivity of hydrogenation of the oil. The consistency of the different batches of the hydrogenated products from the same oil, however, differs within wide limits. In order to get uniform products it will therefore be preferable if the three or four batches hydrogenated with used catalyst are mixed together before packing. After a definite number of hydrogenation charges in this manner, it will be preferable to entirely replace the spent with fresh catalyst for subsequent hydrogenations.

The results with linseed oil show that hydrogenation of the oil takes a very long time and even then a product of softer consistency is obtained. Therefore it is undesirable to take

TABLE I

Hydrogenation of Cottonseed and other Oils

Oil or hydrogenated product	Hydrogenation time		Congeal point °C	Penetration (dial reading mm/10)	Butyrorefractometer reading 40°C	Iodine value (Wijs)	Titre value °C	Component fatty acids %				
	hr.	mts.						Saturated	*Iso*-oleic	Linoleic	Linolenic	Oleic
Refined cottonseed oil (unhydrogenated)	...		...	...	60.56	104.6	34.1	14.8	...	52.8	...	32.4
Hydrogenated product I	2	45	27.8	30	52.84	66.8	35.0	19.6	43.2	8.3	...	28.9
,, ,, II	3	00	28.2	54	53.34	66.6	35.4	19.7	30.6	7.9	...	31.8
,, ,, III	2	45	28.4	51	53.34	65.2	34.6	20.7	44.7	4.6	...	30.1
,, ,, IV	2	40	28.6	48	52.50	63.7	35.4	20.6	46.5	2.1	...	30.8
Refined groundnut oil (unhydrogenated)			...	...	58.16	92.4	31.4	15.8	...	26.9		57.3
Hydrogenated product I	2	10	30.4	34	51.00	57.9	35.7	25.8	37.8	0.1	...	36.3
,, ,, II	2	10	26.6	67	52.00	62.0	34.4	27.8	33.7	2.0	...	36.5
,, ,, III	1	55	26.5	66	51.84	61.8	34.6	29.7	33.6	1.8	...	34.9
,, ,, IV	1	50	26.1	65	51.76	61.6	34.8	30.0	36.5	1.9	...	31.6
Refined linseed oil (unhydrogenated)	...		...	...	74.5	188.9	21.0	8.9	...	23.9	50.2	17.0
Hydrogenated product	4	20	29.6	92	59.0	74.17	43.3	25.0	40.4	0.9	Nil	33.7
Refined mustard oil (unhydrogenated)	...		...	...	62.32	96.0	17.5	11.7	erucic acid 46.5	10.4	2.1	29.3
Hydrogenated product	2	30	29.8	43	54.85	67.6	30.8	25.9	64.4*	0.2	Nil	9.5

* also contained erucic and *iso*-erucic acid.

a highly unsaturated oil for hydrogenation purposes both for the sake of economy and the quality of the product.

The catalyst is evidently poisoned when hydrogenation of mustard oil, which contains a sulphur compound, is carried out; it is well-known that the hydrogenation of the oil is possible if the catalyst is added in two instalments. The first part of the nickel removes the sulphur constituents from the oil and hydrogenation proceeds smoothly when a fresh catalyst is added to such a treated oil. The *iso*-oleic acid content in this case has been exceptionally high; this may be because some erucic acid also comes along with the insoluble lead salts in the separation of fatty acids.[4,5]

Effect of Carriers on the catalytic activity of Nickel in the Hydrogenation of Oils

A carrier or support may be useful in providing a larger contact surface and at the same time a more equal distribution of the catalyst. It also prevents aggregation or caking together and thus preserves the fine dispersion of the catalyst. A carrier may influence indirectly the activity of a catalyst by protecting it from poisons.

For studying the course of hydrogenation of cottonseed and groundnut oils when using supported catalysts, various carriers were employed in the preparation of catalyst from nickel formate: decolourising carbon (Merck), hyflo-supercel (I.C.I.), silica gel (B.D.H.), two samples of Kieselguhr (Merck, Hopkins and Williams) and fuller's earth (B.D.H.). Since it is also mentioned that an excessive amount of the carrier reduces the exposed surface of the catalyst,[6] the above materials were taken in amounts calculated to give a ratio of two parts of nickel to one part of the support. The procedure for the preparation of supported nickel catalyst is the same as that described earlier, only the necessary amount of carrier was ground with nickel formate before adding to the refined groundnut oil and the catalyst was then prepared by heating the mixture in an atmosphere of hydrogen.

The comparative activities of various supported nickel catalysts and the course of hydrogenation of oils were studied as before by conducting the hydrogenation of refined cottonseed or groundnut oils (500 g.) in a Parr medium-pressure hydrogenation apparatus. Catalyst equivalent to 0.2 per cent nickel on the weight of oil was used in each case. Hyflo-supercel (2 g.) was also added. The temperature and pressure of hydrogenation were 176-182°C and 75-90 P.S.I. respectively and the treatment was continued till a slip point of 36-37°C was attained by the fat. After the addition of decolourising carbon and hyflo-supercel (5 g. each) the clear product was obtained by filtration. The characteristics of the products obtained from the hydrogenation of refined cottonseed and groundnut oils using nickel catalyst supported on various carriers are given in Tables II and III respectively.

The results show that by the use of supported catalysts the rate of hydrogenation increases. A neutral support such as carbon, hyflo-supercel and silica gel is superior to a carrier of acidic nature such as fuller's earth or Kieselguhr both as regards consistency and selectivity of the hydrogenated product.

Acknowledgment

The experimental work reported in this paper was carried out by Shri D. D. Nanavati at the National Chemical Laboratory, Poona under a scheme sponsored by the Bombay State Industrial Research Committee.

TABLE II

Hydrogenation of Refined Cottonseed Oil in Presence of Supported Nickel Catalyst

Amount of carrier: one part to two parts of nickel

Oil or hydrogenated product using nickel carrier	Acidity or basicity of the carrier	Hydrogenation time		Congeal point °C	Penetration (dial reading mm/10)	Butyrorefractometer reading at 40°C	Iodine value (Wijs)	Titre value °C	Component fatty acids %			
		hrs.	mts.						Saturated	*Iso*-oleic	Linoleic	Oleic
Refined oil (unhydrogenated)	...	...		...	...	60.5	104.6	34.1	14.8	...	52.8	32.4
No carrier	...	2	40	28.6	48	52.5	63.7	35.4	20.6	46.5	2.1	30.8
Decolourising carbon (Merck)	Neutral	1	20	34.6	28	51.0	60.1	38.8	32.0	35.5	0.4	32.0
Hyflo-supercel (I.C.I.)	Neutral	1	40	33.2	33	52.2	63.1	37.7	30.8	38.4	0.7	30.1
Silica gel (B.D.H.)	Neutral	1	55	35.4	15	50.7	56.1	39.8	35.6	41.6	Nil	22.7
Fuller's earth (B.D.H.)	acidic 0.007% HCl	1	30	30.8	54	51.7	66.5	36.1	28.3	33.1	2.2	36.3
Kieselguhr (Merck)	acidic 0.014% HCl	1	45	30.7	72	54.5	74.4	35.9	22.8	20.8	17.5	38.8
Kieselguhr (Hopkins and Williams)	acidic 0.025% HCl	1	45	28.7	112	55.6	76.1	35.4	27.2	21.7	25.6	25.4

TABLE III

Hydrogenation of Refined Groundnut Oil in Presence of Supported Nickel Catalyst

Amount of carrier: one part to two parts of nickel

Oil or hydrogenated product using nickel carrier	Acidity or basicity of the carrier	Hydrogenation time		Congeal point °C	Penetration (dial reading mm/10)	Butyrorefractometer reading at 40°C	Iodine value (Wijs)	Titre value °C	Component fatty acids %			
		hrs.	mts.						Saturated	*Iso*-oleic	Linoleic	Oleic
Refined oil (unhydrogenated)	...	...		...	...	58.16	92.4	31.4	15.8	...	26.9	57.3
No carrier	...	2	10	30.4	34	51.00	57.9	35.7	25.8	37.8	0.1	36.3
Decolourising carbon (Merck)	Neutral	1	40	33.0	25	51.00	60.6	38.4	29.5	36.0	Nil	34.5
Hyflo-supercel (I.C.I.)	Neutral	1	30	31.2	34	51.30	62.5	36.2	27.7	33.1	Nil	39.1
Silica gel (B.D.H.)	Neutral	1	35	31.6	24	51.10	62.3	37.0	25.4	31.6	Nil	42.9
Fuller's earth (B.D.H.)	Acidic 0.007% HCl	1	35	29.8	34	51.3	62.4	36.8	27.2	29.2	Nil	43.6
Kieselguhr (Merck)	Acidic 0.014% HCl	1	30	26.8	154	54.0	74.3	33.6	23.1	15.4	8.9	52.6
Kieselguhr (Hopkins and Williams)	Acidic 0.025% HCl	1	40	29.2	140	55.6	74.9	33.7	19.8	10.1	8.6	61.5

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2. PLANT HYDROGENATION OF COTTONSEED OIL

By
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The background of industrial fat hydrogenation is reviewed. For production of satisfactory vanaspati from cottonseed oil, prebleaching of the oil with hydrogen in the presence of activated earth and carbon at 110°C under vacuum ("hydrobleaching") and addition of Rufert nickel catalyst after heating the oil to 180°C gave a product not needing post-refining and capable of use to the extent of 25-50% in vanaspati.

Introduction

In 1902 Normann (British Patent 1515, 1903) patented a process for catalytic hydrogenation of unsaturated fats in the liquid state, a process very important in modern oil and fat technology. The objective in the hydrogenation of oil is to bring the hydrogen gas, the liquid oil, and the solid catalyst, namely three phases, into intimate admixture under proper and controlled conditions of temperature and pressure. Hydrogenation is not only of interest as an economic technical process but at the same time is one of the first successful attempts to modify by chemical means the properties of fatty oils in such a way that the edible characteristic remains unimpaired. The object of hydrogenation is to produce more saturated esters, and the products thus have higher melting points, less odour, less colour, and better keeping properties. In industrial practice hydrogenation is often referred to as hardening.

In India the hydrogenation industry started in 1930 with the production of 298 tons of vanaspati only. Today the vanaspati industry is the second-largest food industry in the country, next only to the sugar industry. The production of vanaspati in 1957 was over 3,00,000 tons. With this rapid rise in vanaspati production, the availability of edible oils in sufficient quantities at reasonable prices is becoming a matter of increasing concern. For the manufacture of vanaspati in India, the V.O.P. Controller permits only three vegetable oils to be used, namely groundnut, cottonseed and *sesame*.

Groundnut is the oil chiefly used by vanaspati factories in India. Use of cottonseed oil is not favoured by vanaspati factories because crude cottonseed oil has a dark reddish-black colour and disagreeable taste and odour and the cost of processing is high. There are also technical difficulties in processing this oil and the finished product obtained is not of the white colour generally liked by the consuming public. Government is anxious to see that the vanaspati industry provides an outlet for cottonseed oil in order to encourage its rapid development. The object of this paper is to show how cottonseed oil can be hydrogenated successfully and at minimum cost, so that the way is open for a maximum quantity of this oil to be consumed in the vanaspati industry without affecting the quality of the finished product.

A. Background Considerations

Hydrogenation Reaction

A number of theories according to which hydrogenation of cottonseed oil is reported to proceed have been put forward by various investigators. During hydrogenation there always occurs the production of various fatty acid isomers. Whether present in only negligible or larger amounts, these isomers are an indication that hydrogenation is not a simple reaction but that there are intermediate stages or side reactions of various types. Formation of high-melting *iso*-oleic acid chiefly occurs during the hydrogenation of linoleic acid since such acids are chiefly produced in the early stages of hydrogenation, during the period when the reaction is predominantly one of conversion of linoleic to oleic. In practical hydrogenation, the amount of saturated acids and *iso*-oleic acid produced at a specific iodine value or linoleic acid content, is of paramount importance because of the effect of the two acids on the consistency of the product.

According to Kaufmann the food value of a fat should be improved if the linoleic acid residues are converted by hydrogenation into oleic acid. At the present time however, investigators are more and more agreed that natural linoleic acid has a definite physiological importance as an essential food factor. Several investigators have noted that linoleic acid is essential in food and that its absence leads to all kinds of deficiency phenomena.

The effect of the linoleic contents on the keeping qualities of the fat is of much greater interest. Waterman and Miss Jaaijer found that in general a high linoleic acid content caused a lowering of keeping properties when the fat was exposed to air.

The presence of *iso*-oleic acid is desired in cottonseed oil to be used for vanaspati since *iso*-oleic acid imparts a much-valued grainy texture to the product. It has been shown that in general the percentage of such solid unsaturated fatty acids increases with the selectivity, which is therefore desired. Moreover a high selectivity depresses the linoleic acids contents of cottonseed oil and thus improves quality, and contributes to obtaining a homogeneous product. However, the percentage of *iso*-oleic acids must not be unduly increased because their presence affects the consistency adversely.

In industrial practice a selective hardened fat means one that has only a narrow gap between its melting point and setting point. Selectivity is attainable by carrying out the hydrogenation in such a way that the more unsaturated acids are transformed into the less unsaturated ones in stages.

Factors Affecting Hydrogenation Reaction

These are discussed below.

(1) *Purity of Oil.* It is essential that crude or washed cottonseed oil must be properly and carefully refined and bleached. Hydrogenation proceeds rapidly and economically with a minimum usage of catalyst with an oil which has been properly refined. It is important to remember that impurities in the oil will increase the consumption of hydrogen as well as of catalyst. The time for hardening will also be increased and F.F.A. percentage in the hardened product will be more. Soap in the refined and bleached oil seriously impedes hydrogenation.

(2) *Quality of Hydrogen.* The production of pure hydrogen for hydrogenation is one of the prime considerations in the economical manufacture of hydrogenated fat. There are

several methods for the preparation of hydrogen, but in India electrolytic and steam-iron methods are used by vanaspati manufacturers. High-grade electrolytic hydrogen gas contains at least 99.8% of hydrogen and the principal impurity is oxygen which has no poisoning effect. Unpurified steam-iron gas on the other hand may have a hydrogen content as low as 98.0% and may contain 0.2 to 1.0% carbon monoxide, as well as appreciable traces of sulphur compounds both of which are definite catalyst poisons. It is possible to harden at a low temperature under highly selective conditions with electrolytic hydrogen. Higher operating temperature must be employed with gas of poor quality.

(3) *Quality of Catalyst and Methods of Use.* The quality and amount of catalyst and the method of using the same affects to a great extent the physical and chemical characteristics of the final product as it affects the velocity of the reaction and its selectivity. A good catalyst should be quite active and selective. It should have excellent reuse value, good resistence to poisons and filter out of hardened oils easily and completely to ensure maximum stability in the finished products. Some refiners prefer to manufacture their own catalyst while others purchase it from the market.

There are two methods in general use for the preparation of catalyst, the older being known as the dry-reduction method and the more recent one the wet-reduction process. Nickel formate is generally used for making catalyst in India. Catalyst produced by the wet process is more active, less susceptible to poison and highly selective.

There are three general methods of handling the catalyst.

(i) To start with a small amount of freshly-prepared nickel catalyst is taken and then in each succeeding batch a fresh catalyst is added. Using catalyst by this method the time of hardening for each batch is fairly constant but the consumption of catalyst is a bit high since it is necessary to discard catalyst which is only partially spent. It is also very difficult to separate small amount of catalyst in the initial batches, and moreover a gradual change in operating conditions occurs by increase in catalyst concentration, which affects selectivity.

(ii) In the initial batch 0.5 to 1% of catalyst is used, filtered out and re-used in succeeding batches without the addition of fresh nickel. The catalyst consumption is less and it can be separated out easily because a greater quantity is present, but there is no selective control of hardening.

(iii) The catalyst is allowed to accumulate to the capacity of the filter press. This quantity is then held practically constant by discarding a fraction of the catalyst after each run and adding an equivalent fresh portion of catalyst. This method gives a uniform product and the consumption of catalyst is also less. The third method has been found by us to give very satisfactory results.

(4) *Temperature of Hydrogenation.* Increasing the temperature during hardening increases the rate of reaction and favours selective hydrogenation and the formation of *iso*-oleic acid.

(5) *Pressure and Agitation during Hydrogenation.* Increasing the pressure of hydrogen and rate of agitation decreases the selective nature of hydrogenation.

Hydrogenation Equipment

Practically all fat hydrogenation today is done in batch equipment, of which there are two types:

(i) *Based on Normann's Principle.* Hydrogen is regulated at the bottom of the vertical converters and the excess hydrogen withdrawn at the top by means of a circulating compressor. The compressor blows the excess hydrogen through a purification plant. The agitation of the oil is by stirring. Horizontal autoclaves are also used for this method especially in France.

(ii) *Based on Circulatory System of Wilbuschewitsch.* Hydrogen is introduced in a similar way but is not circulated. Instead the oil containing the catalyst is withdrawn at the bottom and re-circulated from the top of the convertor. The convertor unit is designed to mix intimately under pressure and at elevated temperature the catalyst, the gas and the oil. There is practically no necessity of varying the standard method of operating this unit once the best condition for a given plant and product have been determined unless it is desired to change the characteristics of the product.

B. HYDROGENATION OF COTTONSEED OIL

Hydrogenation Process

The conditions under which cottonseed oil is hydrogenated depends to a great extent on the subsequent processing of the hardened product. In India, this oil is used for the manufacture of vanaspati for food, and hardened oil for industrial purposes. The average fatty acid composition of cottonseed oil is, saturated 25%, oleic 30%, and linoleic 45%.

For the manufacture of vanaspati, the oil should be hardened by using a selective catalyst which will yield a minimum content of saturated acid at a given level of *iso*-oleic acid. Attempts should also be made to remove the maximum quantity of colouring matter, and the F.F.A. of the hardened oil should not be allowed to increase much. During hydrogenation the colour of the oil tends to become lighter and F.F.A. to increase somewhat. In certain cases the latter may be too high and it may become necessary to re-refine the hardened product to bring it down to a satisfactory level. The re-refining is a source loss which may increase the cost of the hardening operation. This can be avoided by controlling the F.F.A. of the refined and bleached oil during hardening. The colour reduction obtained and increase of F.F.A. noted during hydrogenation of cottonseed oil in recent batches treated by us are reproduced in Tables I and II.

The cottonseed oil was hydrogenated at different conditions of temperature and pressure, using varying percentages of nickel catalyst. For obtaining the best results the process described below was finally adopted by us.

Hydrobleaching

Refined and bleached cottonseed oil was taken into the convertor and heated to 110°C under vacuum. At this stage about 0.1% activated earth (Tonsil optimum) and 0.05% activated carbon (Farnell, English) were sucked into the convertor. Hydrogen gas was circulated through the oil for about 2 hours at a pressure of about 15 p.s.i.g.

TABLE I

Colour Reduction and Increase of F.F.A. During Hydrogenation of Cottonseed Oil

(All colour readings in a 5.25-inch cell)

No.	Refined and bleached oil			After hydrobleaching			After hydrogenation			
	Colour		FFA %	Colour		FFA %	Colour		FFA %	M.Pt., capillary slip
	Y	R		Y	R		Y	R		
1.	32.0	4.0	0.04	24.0	3.0	0.05	18.5	2.2	0.09	36.5
2.	32.0	4.0	0.04	23.5	3.2	0.04	19.2	2.0	0.08	36.3
3.	25.0	3.0	0.05	15.0	2.3	0.06	13.5	1.5	0.10	36.6
4.	25.0	3.5	0.05	16.0	2.6	0.06	14.0	1.6	0.11	36.8
5.	30.0	3.5	0.06	23.0	2.8	0.07	17.0	1.7	0.12	36.4
6.	24.0	3.2	0.06	15.0	2.5	0.06	12.0	1.6	0.11	36.6
7.	32.0	3.8	0.07	25.0	2.9	0.08	19.0	2.3	0.13	37.0
8.	32.0	3.5	0.07	25.5	2.8	0.08	20.0	1.9	0.14	36.7
9.	27.0	3.0	0.08	17.5	2.2	0.10	15.0	1.6	0.16	36.5
10.	25.0	3.2	0.08	16.0	2.5	0.09	14.2	1.5	0.18	36.8
11.	25.0	3.4	0.10	15.6	2.7	0.12	14.0	1.3	0.24	36.7
12.	32.0	3.6	0.10	24.0	2.9	0.11	18.0	1.8	0.23	37.0

TABLE II

Effect of Hardening Time on F.F.A. and Colour of Cottonseed Oil

1.	Type of convertor	... Bamag
2.	Charge in tons	... 5.20
3.	Hydrogen gas	... Electrolytic 99.99% pure
4.	Concentration of nickel, %	... 0.05
5.	Temperature of hardening	... 180°C
6.	Pressure, p.s.i.g.	... 20 lbs
7.	Original colour of refined & bleached oil (5.25-inch cell)	... 32.0 Yellow, 3.5 Red
8.	F.F.A. of refined and bleached oil %	... 0.05
9.	After hydrobleaching for one hour	... Colour 25 Yellow, 2 8 Red F.F.A. 0.05%

Time of hardening hours	F.F.A. %	Melting point °C (capillary slip)	Colour reading in 5.25-inch cell	
			Y	R
0.5	0.06	30	23.0	2.8
1.0	0.07	33	20.0	2.6
1.5	0.08	35	18.0	2.4
2.0	0.1	36.5	16.0	2.0
2.5	0.12	37	14.0	1.8
2.0	0.18	39	14.0	1.6
3.0	0.20	42	12.0	1.3

Hydrogenation

After the above treatment was over the temperature of the oil was raised to 130°C under vacuum. Heating was continued to 180°C under hydrogen gas pressure. Now a sufficient quantity of ready-made catalyst or of Rufert Catalyst was taken along with the same quantity of spent catalyst so that the concentration of nickel was about 0.05%. Hydrogen gas was circulated and the pressure was maintained at 20 p.s.i.g. After the desired setting point was obtained, oil was cooled to a temperature of 70-75°C and filtered. It has been observed that different batches of hydrogenated oil vary slightly in characteristics even though they may be hydrogenated under exactly the same conditions. Operating and analytical data for different batches treated by us are given in Table III.

TABLE III

Hydrogenation of Cottonseed Oil—Operating and Analytical Data

1.	Refined & Bleached Cottonseed Oil.	I.V. (Wijs) 106.3
2.	Hydrogen gas used	Electrolytic, purity 99.99%
3.	Nickel %	(a) 0.05% for vanaspati
		(b) 0.1% for industrial hard fat
4.	Temperature of hardening	(a) 180°C for vanaspati
		(b) 190°C for industrial hard fat
5.	Pressure, p.s.i.g.	(a) 20 for vanaspati
		(b) 25 for industrial hard fat

Serial No.	Quantity of charge, tons	Time of hardening, mins.	Melting Point (capillary slip), °C	Setting Point, °C	Iodine value (Wijs)
			For Vanaspati		
1.	5.20	65	33.0	25.0	72.5
2.	6.20	90	35.0	26.2	70.7
3.	5.20	110	36.8	28.0	66.2
4.	5.20	125	36.9	28.6	66.4
5.	6.2	150	39.0	30.9	62.5
			For Industrial Hard Fat		
		hours			
6.	5.20	4.5	59.0	54.3	9.6
7.	5.20	6	62.0	57.0	2.5

In the case of hydrogenation of cottonseed oil it is important to pre-heat the oil to a temperature at which hydrogenation is to begin before the catalyst is added. The catalyst should never be added until the reaction is ready to begin and should be filtered out very promptly as soon as the hardened fat has been cooled at the end of the reaction.

Small traces of metallic catalyst remaining in hardened oil are most potent agents for inducing fat deterioration and discolouration. Therefore, it is vitally important to post-bleach the stock immediately after hydrogenation is complete to ensure removal of every particle of metal from fat.

For the manufacture of hardened product for industrial purposes selectivity is not important. The aim should be to obtain as rapid a hardening as possible by using very active catalyst or by increasing the temperature and pressure during hardening.

Discussion and Conclusion

Tables I and II indicate that the colour of refined and bleached cottonseed oil becomes much lighter after hydrobleaching and hydrogenation. The F.F.A. also increases during hydrogenation although this is negligible during hydrobleaching. The colour and F.F.A. of the finished product are also affected by the time of hardening. If the F.F.A. of refined and bleached oil is kept between 0.04 to 0.07 per cent and the hardening time below two hours, the hardened product will have a satisfactory level of F.F.A., and there is absolutely no necessity for re-refining it. By avoiding re-refining the cost of hydrogenation can be greatly reduced. There is also much saving of activated earth and carbon if colour is removed during hydrobleaching and hydrogenation and this will further reduce the overall cost.

It has been observed by us that if the setting point of finished product is kept between 27.5 to 29°C and the difference between melting point and setting point is kept between 7 to 8°C the final product will be very good for use as vanaspati. Table III indicates that if hydrogenation is done according to the conditions specified, the resultant product will fulfil these requirements. It has also been observed that catalyst consumption can be much reduced if the method of using the catalyst recommended by us is adopted. The colour of the hydrogenated product ranges from 19.0 Yellow, 2.3 Red to 19.0 Yellow 1.5 Red, varying as shown in Table I. A product of this colour can be used to the extent of between 25 to 50% after post-bleaching and deodorising in vanaspati, and the product will be of quite good colour acceptable to the consumer without objection. The only defect in using cottonseed oil in vanaspati is the fluorescence which does not diminish by any treatment known to us. It gives an impression in the minds of users that mineral oil has been added.

DISCUSSIONS

DISCUSSION LEADER: DR. J. S. AGGARWAL,
(*Regional Research Laboratory, Hyderabad*)

J. S. Aggarwal. Only two papers have been presented on the hydrogenation of cottonseed oil. I shall discuss and give my observations on both the papers together and also report some of the recent work carried out on the various operating conditions in the hydrogenation of cottonseed oil.

Shri P. N. Mathur, Manager and Chief Chemist, Snow White Food Products Co. Ltd., Howrah, brings out some interesting observations on the subject. The object of hydrogenation is to produce more of saturated esters having a higher melting point, less odour and colour, and better keeping properties. Cottonseed oil is one of the three oils permitted by Government for the manufacture of vanaspati. On account of the technical difficulties in processing this oil and because the finished product is not of white colour, use of cottonseed oil has not been favoured in India for vanaspati manufacture although most of the oil produced in the U.S.A. is hydrogenated to oleomargarine and shortening. The Government has now desired that at least ten per cent of cottonseed oil be used in vanaspati; it is therefore considered imperative to study the course of hydrogenation of this oil. Formation of high melting *iso*-oleic acids chiefly occurs during the hydrogenation of linoleic acid, and they are produced during the earlier stages of hydrogenation at the time when the reaction is predominantly one of conversion of linoleic to oleic acid. In practical hydrogenation, the amount of saturated acids and *iso*-oleic acids produced at a specific iodine value or linoleic acid content is of paramount importance because of the effect of these two acids on the consistency of the product.

Shri Mathur observes that the percentage of *iso*-oleic acids in vanaspati manufacture must be kept as low as possible because their presence affects the consistency adversely. This point requires a little further consideration. Optimum selectivity increases in different hydrogenated food products in the order: ordinary shortening, high stability shortenings or frying fats, margarine oils. The characteristics for vanaspati are very similar to those for margarine oils. It should be relatively firm at low temperatures, but must be substantially free of glycerides which will not melt at the temperature of the mouth. In its manufacture, therefore, it is absolutely essential to avoid any considerable formation of saturated acids and to build up the required low temperature body largely through the formation of *iso*-oleic acids. This will be achieved by the use of a relatively selective catalyst which will yield a minimum content of saturated acids at any given level of *iso*-oleic acids. Further it is well-known that selective hydrogenation always leads to the maximum formation of *iso*-oleic acids.

Shri Mathur points to the following five factors affecting hydrogenation reaction.

(1) Purity of oil
(2) Quality of hydrogen
(3) Quality of the catalyst and method of using the same
(4) Temperature of hydrogenation
(5) Pressure and agitation during hydrogenation

These may now be considered.

Purity of the Oil

Vanaspati manufacturers in India have been reluctant to handle cottonseed oil because of high refining losses, dark colour of the oil leading to higher bleaching costs, and inability to produce a light-coloured oil acceptable for vanaspati manufacture. Impurities in the oil increase the consumption both of hydrogen and of the catalyst. Soap in the refined and bleached oil seriously impedes hydrogenation. Some of the factors in storage of cottonseed and of crude oil (based on the work carried out at the Regional Research Laboratory, Hyderabad), and refining of the oil by the Sharples method and continuous "low-loss" refining process have been discussed by S. Mazumdar in his paper on the "Utilisation of cottonseed oil for the production of vanaspati" (Chemical Age of India, 1958, *9*, 419). The author concludes: "A co-ordination of good storage conditions for cottonseed, followed by good processing and technique for extracting the crude oil, and the right choice of a continuous refining process can put at the disposal of the vanaspati manufacturer a high-quality refined cottonseed oil which would be economical to use and would meet the required standards of the industry."

Quality of Hydrogen

A very pure hydrogen free from carbon monoxide and other poisonous gases is necessary for the oil hydrogenation industry. Higher operating temperature must be employed with gas of poor quality. In India, electrolytic hydrogen which is of a high purity is mostly employed but hydrogen prepared by the steam-iron method is also used sometimes.

Quality of the Catalyst and Methods of Using the Same

A good catalyst must be both active and selective. It should have excellent re-use value, good resistance to poison and should filter out of hardened oils easily and completely. As regards the re-use of the catalyst, the third method based on discarding a fraction of the used catalyst after each run and adding an equivalent fresh portion, has been found by the author to give a uniform product leading to satisfactory results (Paper 1). The results given in Table I of Paper 2 also show that re-usage of the catalyst does not materially affect the selectivity of hydrogenation of the oil, especially with cottonseed oil. But the consistency of the different batches of the hydrogenated product differs within wide limits and for the sake of a uniform product it has been suggested that three or four such charges be mixed before packing. Further it is preferable if the catalyst in use is entirely replaced by fresh catalyst after a few hydrogenation charges. That the re-usage of the catalyst decreases the selectivity to some extent in the case of groundnut oil is well-known. The number of times that the same catalyst can be re-used entirely depends upon the conditions of hydrogenation and the product desired to be obtained.

It is well-known that the selectivity of hydrogenation and the concurrent formation of *iso*-oleic acids are favoured by a greater catalyst concentration. The work carried out at the National Chemical Laboratory, Poona (Aggarwal and Nanavati, Proc. Oil Tech. Assoc., 1956, *12*, 13), however, shows that in a laboratory Parr-hydrogenator the selectivity increases upto a certain concentration of the catalyst (0.2%) after which it remains almost unchanged.

In a favourable selective hydrogenation of cottonseed oil, according to Hilditch and Moore (J. Soc. Chem. Ind., 1923, 42, 15-17 T) the saturated acids start increasing only after the linoleic acid content is reduced to about ten per cent.

Temperature of Hydrogenation

Bailey, Feuge and Smith (Oil and Soap, 1942, *19*, 169) report that selectivity is enhanced by increasing the temperature of hydrogenation, and that formation of *iso*-oleic acids also increases at higher temperatures. Aggarwal and Nanavati (*loc. cit.*) find this to be the case in the hydrogenation of groundnut oil upto a maximum temperature of 182°C above which hydrogenation becomes non-selective, as evidenced by the presence of increased quantities of linoleic acid. Markley ("Fatty acids", 1947, page 368) summarised the views of various workers that this may be due to the dehydrogenation which accompanies the hydrogenation of the fat at high temperatures.

Pressure and Agitation During Hydrogenation

It has been reported (Bailey *et al., loc. cit.*) that increase in the hydrogenation pressure decreases the selectivity and also inhibits *iso*-oleic acid formation. In their laboratory experiments, Aggarwal and Nanavati (*loc. cit.*) find this to be the case upto a maximum of 65-70 p.s.i. But at higher pressures selectivity again increases. At low pressures (10 p.s.i.) the time required for hydrogenation is more than needed at higher pressures to bring the fat to the same consistency. The rate of agitation also affects the selectivity of hydrogenation.

The various conditions of hydrogenations mentioned above, however, will vary from one hydrogenator to another to get a hardened fat of similar characteristics.

Shri Mathur has further given in Paper 2 the most suitable conditions found by him for the hydrogenation of cottonseed oil in which re-refining can also be avoided. The only defect in using cottonseed oil in vanaspati, according to Shri Mathur, is the fluorescence which does not diminish even after various treatments. Further work is required as to the nature of this fluorescence and the means of removing it.

Besides some of the observations already discussed the second paper points out that due to the presence of much more linoleic acid in cottonseed oil than in groundnut oil, the hydrogenation should be very selective. It also gives some of the findings on the hydrogenation of linseed and mustard oils.

With the use of supported catalysts the rate of hydrogenation increases. Neutral supports such as carbon, hyflo-supercel and silica gel have been found superior to carriers acidic in nature both as regards consistency of the hydrogenated product and selectivity of the hydrogenation process.

Eldib and Albright (Ind. Eng. Chem., 1957, *49*, 825) from their laboratory studies on the hydrogenation of cottonseed oil have recently come to somewhat different findings than those mentioned above as regards various operating variables in the process. Some of their more salient observations are summarised below.

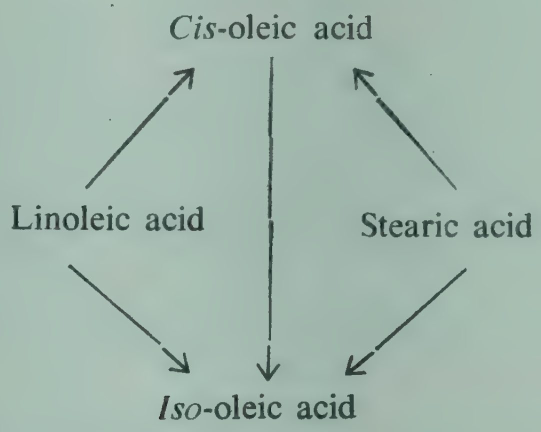
1. *Effect of Temperature.* Hydrogenation of different batches of cottonseed oil between 115 and 160°C indicated little change in linoleic acid contents (selectivity) with temperature. Slightly more *iso*-oleic acid was formed at higher temperatures.

2. *Effect of pressure.* Both selectivity and isomerisation decreased with increased pressure from 20 to 100 p.s.i. A pressure increase from 100 to 140 p.s.i., however, had only a small effect on either factor. These findings are very similar to those of Aggarwal and Nanavati mentioned above.

3. *Nickel Catalyst Concentration.* Selectivity and isomerisation were not significantly affected by increases in catalyst concentration.

4. *Agitation.* Low agitation resulted in more selective hydrogenation and an increased *iso*-oleic acid content. But at low agitation (550 R.P.M.) the rate of hydrogenation slows down considerably.

Mechanism of Hydrogenation of Cottonseed Oil. The main reactions in the hydrogenation of cottonseed oil are probably as follows:



The work of Eldib and Albright and that of Bailey (J. Amer. Oil Chem. Soc., 1949, *26*, 644) indicate that increased selectivity and *iso*-oleic content occur simultaneously. Selectivity by definition results in higher reaction rates for linoleic acid than for oleic acids. Selective absorption of linoleic acid compared to oleic acids on the catalyst surface might explain this phenomenon. It could be reasoned that when linoleic acid displaces oleic acid on the catalyst surface, *cis*-oleic acid will in most cases be converted to *iso*-oleic acids. Positional isomerisation, however, cannot be explained by this mechanism. The Allen and Kiess theory (J. Amer. Oil Chem. Soc., 1956, *33*, 355) postulating hydrogenation and dehydrogenation by a free radical mechanism seems to explain satisfactorily both positional and geometrical isomerisation. Their data indicate that some double bonds of linoleic acid may wander on the chain and in addition *cis-trans* isomerisation of some double bonds may occur before either double bond hydrogenates.

The data of Allen and Kiess, however, indicate that in a mixture of linoleic and oleic acids all *trans* isomers of oleic acid are obtained only by partial hydrogenation of linoleic acid. But when tallow or greases are selectively hydrogenated, the amount of *trans*-oleic acids produced is sometimes greater than the original amounts of linoleic and linolenic acid groups. A considerable portion of *trans-iso*-oleic acids must result, therefore, from iso-merisation of *cis*-oleic acid. It appears that more studies will be necessary before the mechanism of production of *trans*-oleic acids in oils such as cottonseed oil can be definitely determined.

Regarding the role of the catalyst, it has been suggested that molecular hydrogen is adsorbed and dissociated on the nickel catalyst. Double bonds of the fat react with either adsorbed atomic hydrogen or atomic hydrogen desorbed from the catalyst. Selective hydrogenation is then explained by the fact that atomic hydrogen has a greater probability of meeting and reacting with polyunsaturates because of selective adsorption than mono-unsaturates. The role of the catalyst, therefore, is to produce atomic hydrogen either on or near the catalyst surface and to cause selective adsorption of the acids so that selectivity occurs.

As is well known, the hydrogenation of oil to a low iodine value to yield hard oil or stearin is the simplest of hardening operations in as much as the factors of selectivity and *iso*-oleic acid formation are not involved. As cottonseed oil contains a substantial amount of palmitic acid (about 23%) in its composition the fully-hardened fat will be a good material for soap manufacture.

What has been said only relates to hydrogenation of the oil by the batch process. We may also consider some aspects of continuous hydrogenation. A plant for continuous hydrogenation for oils was obtained sometime ago by the Tata Oil Company. Subsequently they have switched on to batch hydrogenation. I would request Shri T. V. Subba Rao to give some further information on the continuous hydrogenation.

T. V. Subba Rao. The standard continuous hydrogenation unit of Bolton and Lush was in use for several years in one of our plants. The assembly consisted, I believe, of seven cylinders. The catalyst consisted of nickel spiral coils cage encased in vertical cylinders. The handicaps in this system are the possible lack of uniformity in the activity of the catalyst and the greater control needed in regard to adjustment of time of contact of the flowing oil with the stationary catalyst. The hydrogenated product, as is well-known, is characterised by a notable lack of selectivity compared to the batch process. In view of all these, the continuous unit needs greater technical skill and hence the more flexible batch unit gains preference. The greater uniformity in quality obtainable for the product from batch to batch is another reason in favour of the batch process over the continuous.

C. R. Das. Procter and Gamble in the U.S.A. have the only unit working by continuous hydrogenation. D.C.M. Chemical Works is trying to import such a unit for their use.

P. N. Mathur. The first plant on continuous hydrogenation was run at the Ganesh Flour Mill in 1927 but could not be worked.

Rajeshwar Prasad. In the continuous hydrogenation plant at Lyallpur (Punjab), the difference between the melting point and setting point of the fat was more than 14°C whereas in the usual batch hydrogenated product it is only 9°C.

N. G. Chatterji. From the paper of Dr. Aggarwal it appears that linoleic acid during hydrogenation mostly changes to *iso*-oleic acids. *Iso*-oleic acids are not generally present in natural oils and fats but are the result of the hydrogenation of oils; is any information available on their nutritive value?

F. G. T. Menezes. Some work has been carried out at the Nutrition Research Laboratory, Coonoor where it was found that *iso*-oleic acid has no harmful effect.

W. J. H. Bendixsohn. Old plants for continuous hydrogenation had the defect that they were not constructed to give a high *iso*-oleic acid content, and also mixing with catalyst was not good.

As regards *iso*-oleic acids, Dr. Normann himself started tests on various samples of margarine. All data showed that *iso*-oleic acids are not deposited in the human body.

B. S. K. Shastry. Use of carbon during hydrogenation of oils results in the reduction of colour. It may be due either to the adsorption of colour by the carbon, or to hydrogenation. If we know the exact mechanism by which the colour is removed, it may be possible to affect some colour improvement by this means.

G. Khandwala. A continuous hydrogenation plant was used by us for six years; a metallic taste was found in the product.

S. A. Saletore. No matter what may be the melting point of the fat, the calorific value has been found almost the same. Hydrogenated oil lacks some of the essential fatty acids like linoleic acid. The linoleic acid is an important factor for reduction of cholesterol content of blood. Armour and Co. of America are putting out a safflower oil product for alleviation of atherosclerosis.

W. J. H. Bendixsohn. Addition of 5 per cent *sesame* oil to vanaspati gives the necessary amount of linoleic acid. Mixed diets give sufficient quantities of these essential acids.

F. G. T. Menezes. Some reference has been made during these discussions to the reported deficiencies of vanaspati, both generally in regard to its nutritive value and specifically in relation to increased susceptibility to heart disease. As most of us here are aware, some doubt in regard to the nutritive value of vanaspati had, in fact, arisen in 1947, following the adverse findings in this regard reported by the Izatnagar laboratory. But systematic confirmatory work since carried out at various national laboratories at the instance of the Government of India, both on rats and rabbits as well as on human beings, has completely dispelled these doubts as unwarranted. While vanaspati of melting point 41°C (as was being manufactured at that time) was not found to be well absorbed in the system, the product of 37°C melting point was found to be as harmless on the one hand and as nutritive on the other as the raw and refined groundnut oil from which it was made. Following these findings the melting point of vanaspati was statutorily limited to a maximum of 37°C; further, with a view to improve the nutritive value of the product with reference to that of ghee, the addition of vitamin A at the same level as found in good cow's ghee was made compulsory.

The association of vanaspati with heart disease is a very recent development, originating from some work in South Africa and the U.S.A. which appeared to indicate that consumption of animal fat or hydrogenated vegetable oil tends to increase the serum cholesterol level of blood which in turn is associated with increased susceptibility to atherosclerosis but this work is still in a purely hypothetical stage and a large amount of research has yet to be carried out on various related points before any definite conclusion can be drawn.

In India, the addition of 5% *sesame* oil to vanaspati, which has been made compulsory in order to provide a ready test for detection of adulteration of vanaspati in ghee, also ensures the presence of a minimum of 2% linoleic acid. This, with the residual linoleic acid present in the hardened oil (due to the hydrogenation not being entirely selective) results in vanaspati having an essential fatty acid content of 2 to 5% which compares very well with that of ghee. Incidentally, vanaspati actually appears to have an advantage over ghee in this regard, in that while ghee itself contains cholesterol, vanaspati does not contain any. The entire question is under examination by the Cardiovascular Sub-Committee of the ICMR who are understood to be promoting the necessary research in this connection.

J. P. Varma. The work at the Central Drug Research Institute, Lucknow has shown that coconut oil is superior nutritively to other oils. Animals can manufacture essential fatty acids from short chain fatty acids.

N. G. Chatterji. The difference between vanaspati and natural oils lies in the presence of *iso*-oleic acids in the former fat. The physiological effect of *iso*-oleic acids on the human body has to be found out.

F. G. T. Menezes. The work mentioned by him before, and as reported in a CSIR monograph, has shown that *iso*-oleic acids have no adverse physiological effect on mammals.

N. Bhojraj Naidu. In the work reported by Dr. Aggarwal, characteristics of samples periodically withdrawn during the course of hydrogenation might have given useful information.

In the case of mustard oil, the catalyst was used in two stages; the first part might have been employed for the removal of sulphur.

Experimental results have shown that the lack of essential fatty acids has a deleterious effect on the human system.

K. S. Murti. The entire western world uses solid fats. Tallow which is extensively used contains considerable quantities of saturated acids.

T. V. Subba Rao. People in Kerala do not suffer from any deficiencies even though they have used coconut oil continuously for a very long time.

K. T. Achaya. The earlier work of Deuel has shown that rats could be maintained in quite normal condition even over 150 generations on an adequate diet with hydrogenated oil as the source of fat.

A recent paper, of which the speaker is a co-author, from the same laboratory shows the importance of essential fatty acids for maintaining a balanced blood and liver lipid-pattern.

In coconut oil, lauric and myristic acids are not converted to essential fatty acids, but can function like them as cholesterol-clearing and transporting agents in blood.

Cholesterol accumulation was once thought to be exclusively due to essential fatty acids in diet, but a high total calorific level of the diet was also usually found associated with atherosclerosis, and a high saturated fatty acid content of the diet was also found to occur. That diet and not genetic factors was involved is shown by the higher incidence of atherosclerosis among American Japanese as against Japanese in Japan or in Hawaii.

Instead of merely disregarding the accumulating evidence in regard to essential fatty acid deficiency, the vanaspati industry would do well to take heed of it as a portent for the future.

J. S. Aggarwal. I do agree with Dr. N. G. Chatterji that in our studies on the hydrogenation of cottonseed oil, most of the linoleic acid appears to change to *iso*-oleic acids. This may be due to the fact that we worked with the nickel catalyst under conditions leading to the most selective hydrogenation.

As Dr. Bhojraj Naidu has suggested, it would certainly have been more informative if periodical samples of the material during hydrogenation had been taken and the characteristics determined, but for the work in view at the time the investigation was under taken, this was not considered necessary.

Much has been spoken about the nutritive value of vanaspati and considerable research work in this direction has been done and is also in progress. But we have to consider one practical aspect. We in India have been taking vanaspati for more than sixteen years and no harmful effect has yet been noticed. On account of its high price and almost universal adulteration, ghee is not available to the general public and vanaspati is the only substitute for those people who are accustomed generally to hard fats in their food materials.

The Indian public is in a favourable position as regards essential fatty acids because we generally take raw soft oils as a portion of our fat requirements.

SECTION VI

BY-PRODUCTS

Discussion Leader: Shri G. V. Sirur,
Sundatta Cottonseed Utilisation Ltd.,
Hubli.

1. BY-PRODUCTS OF COTTONSEED CRUSHING INDUSTRY—A REVIEW

By

OM PRAKASH, ATMA RAM & S. C. PANDEY

(Harcourt Butler Technological Institute, Kanpur)

The importance of developing the cottonseed crushing industry in India has been emphasized and a survey of the utilisation of different by-products of the industry, viz. linters, hulls, cake, refining foots, and colouring matter has been made with a view to developing the utilisation of these by-products side by side with the development of the crushing industry.

India is an important cottonseed-producing country producing about 17 lakh tons of cottonseed annually and ranking fourth among the cottonseed-producing countries of the world. The seed contains on an average about 20% of oil and as such is a valuable source of it. But whereas the processing of cottonseed for its oil, cake, etc. in advanced countries such as the U.S.A. and U.S.S.R. has grown apace, cottonseed crushing in India has not made much headway so far. The present crushing capacity of cottonseed in India is estimated at about 2,77,000 tons per annum, but only about one-third of this quantity is actually crushed at present. However, with the implementation of the Second Five-Year Plan and with the emphasis laid on the augmentation of the oil and fat resources of the country, every attempt is being made to develop the cottonseed crushing industry of the country. In the Second Five-Year Plan the target for the production of cottonseed oil by 1960-61 has been fixed at 30,000 tons.

With the development of the cottonseed crushing industry, the question of utilisation of the by-products of the industry becomes important, as the economic development of any industry depends upto the proper commercial utilisation of its by-products.

Cottonseed as it comes from the gin consists of three parts:—(i) linters, short fibres left attached to the hulls after the ginning process, (ii) hulls, the dark-coloured outer horny covering, and (iii) kernels, the soft matter inside the hulls which is the store-house of the oil. The proportion of linters varies between 2.5% in the indigenous varieties to about 10% of the weight of the seed in the American varieties. The delinted whole seed contains about 44% of hull and 56% of kernels. Linters and hulls are the first by-products of the industry. Further by-products are cottonseed cake obtained during actual crushing and foots and pigments obtained during the oil-refining processes.

Linters. Apart from the true fibres or lint, the seed bears a number of short fibres called linters. Besides cellulose, these contain pectic substances, mineral and nitrogenous constituents, waxes and resins, colouring matter and water-soluble constituents. They provide important raw materials for many industries. The degree of advancement of the cottonseed processing industry in the U.S.A. may be gauged from the fact that seven different grades of linters, based upon fibre-length, colour, and trash present, have been adopted by the U.S. Department of Agriculture, for use for different specific purposes. The low-grade varieties are used as stuffing material for preparation of mattresses and upholstery for furniture and automobile industries and in the manufacture of coarse cotton yarn. Purified and bleached cotton linters are used to some extent in paper making, as floc for plastic fillers and artificial suede and in the preparation of surgical dressings. The use of cotton linters permits the production of chemical cellulose of high ∝ - cellulose content and of high viscosity. Second-cut linters, after mechanical and chemical purification, are used in the manufacture of superior cellulose, cuprammonium rayon, high-strength viscose, lacquers, smokeless powder, sausage casings and other cellulose products in which a high quality is required. Tire cord rayon is made from chemical cotton (purified cotton linters) in order to obtain the superior fatigue strength so necessary in tires, specially those for trucks and buses. The Rayon Panel has envisaged a production target of 60-70 tons of rayon per day, which would require more than 20,000 tons of cellulose material; approximately 80,000 tons of linters, going waste in India at present, would be an ideal material for consumption for this purpose. Among other chemical uses, it also is employed in nitrocellulose industry. During World War I, considerable quantities of linters were employed in the production of explosives. Cotton linters also contain wax and resins. The presence of a coating of wax on cotton fibres was first reported by Schunck[1] in 1868. He separated a portion of wax from the fibre which resembled carnauba wax and had a m.p. of 83-84°C. The amount of wax which may be extracted from the lint with organic solvents normally ranges from 0.4 to 0.7%. Conrad[2] has found out that the green-lint cotton, *Gossypium hirsutum* (var. Arkansas green-lint) contained a much higher quantity of wax, *viz.*, 14-17% of higher melting point.

Hulls

For many years, hulls were thrown away or, as stated by Tompkins[3] and others, used as a fuel to run the oil mills. They are now used extensively as a roughage in livestock feed, either alone or in mixture with cottonseed cake, being superior to certain hays and grasses. In India, some 20,000 tons of hulls per annum may be available at present, and can be put to several valuable uses if the industry for the utilisation of these wastes is developed on lines similar to that in the U.S.A. These hulls are bulky and from the external covering that encloses and protects the seed kernel. Chemically cottonseed hulls consist of 3 major components: pentosan, cellulose and lignin, as well as smaller quantities of protein, fat and mineral matter. A typical analysis of commercial cottonseed hulls is as follows (% by wt.):—Moisture 8-9, oil 1, protein 3.5, carbohydrates 38, crude fibre 46 and ash 2.6. Markley[4] has reported that dry cottonseed hulls contain about 50% crude cellulose or cellulose complexes which contain pentosans as well as alpha and beta cellulose. In addition, the hulls yield about 23-25% each of lignin and furfural.

Cottonseed hulls have been put to various industrial uses, which can be classed in two groups—firstly, those uses in which the hulls are employed as a bulk material without previous chemical treatment, and secondly where the hull is treated by chemical means before use. In the former group fall its use as animal feed, as a soil conditioner, in phenolic plastics, etc. The lignin and carbohydrate constituents tend to build up the humus content of soil. The ash of the hulls contain large amount of Ca, Mg, some P and K. They have, therefore, proved to be a satisfactory fertilizer, particularly as a source of potassium. The hulls have been suggested as a filler for phenolic moulding compounds. It has been shown that the absorbing power of the hulls is a function of their particle size and fibre content. A maximum impact strength was obtained when the hull filler had a particle size of 100 mesh and contained 10% fibre. Besides these uses, the hulls find an outlet in making packing and stuffing material in the manufacture of baseballs and horse collars, insulating articles for house construction, paper manufacture, linoleum, sweeping compositions and in the preparation of insecticidal poisons for grasshopper control.

Furthermore, the chemically-treated hulls are a source of tannin,[5] cellulose,[6] xylose,[7,8] lignin, furfural,[9] etc. The tannins, which may be extracted with hot water,[5] are reported to be suitable for use in industrial tanning solutions. The hulls are a substantial source of cellulose, which may be obtained more or less pure by cooking the hulls in hot dilute NaOH. This cooking removes the major part of the pentosans and lignin. After bleaching a white cellulosic product is obtained. The pentosans are hydrolysed to xylose by hot dilute mineral acids. The solid lignin residue obtained after the saccharification processes has been suggested for use as a plastic filler[10] and a soil conditioner.[11] It may be converted into vanillin and other chemicals.[12] Despite all these suggested uses, most of the lignin is used at present as a fuel. Cottonseed hulls, however, excel all other plant materials and are on a par with oat hulls as a source of manufacture of furfural, prepared by the usual digestion method[13] in a yield of about 17.5%. Other uses of the hulls include the preparation of carbon for use as a pigment in oils and paints and for manufacture of electrodes. Products of destructive distillation are used as wood preservatives. The hulls when destructively distilled at about 650°F yield mainly acetic acid, methanol, charcoal, tars, tar oils, creosotic derivatives and gas. Randolph[14] stated that the recovery of acetic acid from the destructive distillation of hulls is sufficiently high (approx. 3.9%) to make the process commercially attractive.

Preparation of activated carbon is yet another use for the hulls. Musser[15] in 1940 suggested a method of preparation of activated carbon from cottonseed hull bran. Cottonseed hulls after removal of pentosans by acid hydrolysis are reported to produce an activated carbon of high decolorising power. This is one of the significant uses to which the hulls may immediately be put in India, along with similar waste material from other oilseeds such as neem, castor and groundnut.[16] This is important to meet the requirements of activated carbon of this country, the demand for which in the past has been met mostly by importing standard qualities of foreign makes.

Cottonseed Cake

This is mostly used abroad as cattlefeed for dairy and beef cattle, sheep, pigs, etc. in different forms, and as a fertilizer. Other uses, such as for technical protein products and plastics, are being developed. In India, however, cottonseed is mostly used for feeding cattle in the form of whole seed, which is a very wasteful practice. Careful experiments have shown that animals can grow on rations containing very small amounts of fat but which supply sufficient amounts of protein, minerals, vitamins and carbohydrates. Athawale,[17] on the basis of the analysis of 88 samples, has shown that the decorticated cottonseed cake is nearly twice as rich in protein as cottonseed. Moreover, the fuzz present on the whole seed is fibrous and rather hard to digest, whereas the cake is rich in phosphorus and vitamin B and mixed with hulls, bran and hay is an excellent nutrient for cattle, dairy and farm sheep, horses, poultry, etc. The large amount of oil in cottonseed not only makes it an uneconomical feed, but is likely to cause cows to go "off feed." Further, cream obtained from cows fed on cottonseed churns into a hard, tallowy butter. Some years ago, it was a common belief that cottonseed meal and raw cottonseed caused blindness, swelling of the joints and loss of appetite in cattle. At one time, these effects were attributed to the pigment gossypol, a complex phenolic substance of high molecular weight. Now it has been established that the disease was actually due to lack of vitamin A, and not to anything contained in cottonseed or its meal.[18,19] Experimental studies undertaken at the Indian Veterinary Research Institute, Izatnagar have definitely established the fact that the nutritive value of cottonseed cake is nearly the same as that of whole cottonseed. It is, therefore, a happy sign that our Government is going to launch an intensive educational campaign to encourage the feeding of cattle with cottonseed cake.

Furthermore, the use of cottonseed meal as a source of food for human beings has attracted the attention of various workers in America. Cottonseed flour, named 'Alison Flour' after its originator, is coming into increased use for admixture in wheat flour. This flour is 25 times as nutritious as potatoes, 5 times as nutritious as corn meal and 4 times as nutritious as oat meal. The flour has a light colour and a slight, pleasant and characteristic nutty flavour remarkably stable in storage. Use of the flour has been found advantageous in a variety of baked products and confections.

The use of oilcake as manure in India is well-known. However, its consumption is not as much as it should be. Cottonseed meal and other oilseed meal fertilizers, although relatively expensive sources of plant food, are valued for certain reasons. The value of organic manure from cake mainly lies in the quantity of nitrogen supplied, which is much higher in oilcake than in ordinary stable or farmyard manure. Besides nitrogen, cottonseed cake is a rich source of potash and phosphoric acid. The decorticated cake contains approximately 6.6% nitrogen, 1.6% potash and 2.8% phosphoric acid. Cottonseed cake is recommended as a particularly effective 'fertilizer' for fish ponds. This cake combines the advantages of slow decomposition, moderate cost and lack of salinity and alkalinity, and has been applied with success to wheat and maize, alone or with superphosphate. It is reported to give better results than a mixture of superphosphate and nitrate.

The carbohydrate fraction of cottonseed meal is a good source of raffinose, the best-known trisaccharide (a rare form of sugar), used in the preparation of certain culture media. Some 2-4% raffinose may be obtained from commercial cottonseed meal.[20] Different methods for its preparation have been suggested from time to time. Raffinose itself has no reducing power, but is converted completely by strong mineral acids to the monosaccharides fructose, glucose and galactose.

Industrial protein from oilcakes has not received much attention in our country, although work on synthetic fibres from cottonseed cake has been carried out in foreign countries. Interest in cottonseed protein, adhesives, plastics, water paints, etc. may be expected to increase in due course with the availability of solvent-extracted cottonseed cake.

Foots

The foots obtained in refining cottonseed oil contain, besides pigments, resins, waxes and other impurities, about 8-20% of neutral oil and 20-50% of fatty acids in the form of soap.[21] The foots may be used directly in soap manufacture and in conjunction with other soap bases, they produce household and laundry soaps of standard quality with good detergent and lathering properties.

The foots may also be employed for processing into fatty acids. Several operations are involved in the process: (i) pretreatment of foots involving completion of saponification, liberation of fatty acids by treatment with mineral acids, and removal of impurities by washing, (ii) distillation of fatty acids under reduced pressure with superheated steam, (iii) fractional distillation, batch or continuous, of the fatty acids to get commercial palmitic acid and a commercial mixture of oleic and linoleic acids. Recently a method has been proposed for the production of technically pure stearic acid by hydrogenation of the unsaturated fatty acids. The residue left in the stills is pitch.

Cottonseed fatty acids have found extensive use in the soap and rubber industries in the U.S.A. In the rubber industries they are used as an ingredient in compounding. They have also been used for the manufacture of alkyd resins, greases and lubricants, and as an intermediate compound in the manufacture of a host of chemicals—long-chain amines, amides, nitriles, quaternary ammonium compounds, esters, alcohols, metallic salts, amine salts, ketones and many others, which may subsequently be used in the manufacture of synthetic surfactants and detergents, modifying agents in plastics and resins, germicides, floating agents in paints, ore floatation, plasticizing agents, waterproofing compounds, etc.

The residue (pitch) left after distillation consists of non-volatile fatty acids, polymerized fatty materials, unsaponifiable matter and impurities. It can be used as a caulking compound, waterproofing and insulating material and in the manufacture of anti-rust paints.

Cottonseed oil foots have also been investigated for obtaining motor fuel and allied products by pyrolysis.[22] A yield of 21% crude oil, giving on distillation 31-35% gasoline and 43-50% kerosene, is reported to have been obtained.[23]

Pigments

Pigments of cottonseed afford yet another interesting and important field for study, isolation and utilisation. Many of the technical problems in regard to cottonseed and its oil arise mainly from the high pigment content.

The chief pigment in cottonseed kernel is gossypol which is present to the extent of 2%.[24,25] It is a phenolic compound of light yellow colour and toxic properties. The other important pigments are gossypurpurin, gossycaerulin and gossyfulvin. Several other pigments have also been reported. Most of the pigments of the kernel are reported to be concentrated in distinct morphological structures, the pigment glands, which are reported to be peculiar to cottonseed and some related genera.

Since the first isolation of a yellow pigment by an English chemist[26] in 1886, a number of methods have been proposed for the extraction of the pigments of cottonseed, chiefly gossypol. A laboratory gland-floatation process[27] was developed in 1946 for the mechanical separation of most of the cottonseed pigments in the form of intact pigment glands. Because of the high concentration of gossypol in the pigment glands, and the ease with which it is freed of accompanying impurities, these pigment glands may constitute an excellent source of pigment for commercial application.

The pigments of cottonseed oil may be used for diverse purposes, depending upon the character of the pigment. A yellow pigment obtained from the foots may be used as a dye for silk and wool. Gossypol is reported to be one of the most active antioxidants of vegetable origin,[28] and can be used in edible oils being practically non-toxic in low concentrations.[29,30,31] The presence of gossypol in small amounts is reported to result in lower refining losses,[32] and as such may be utilised as a refining aid.[33,34]. It is also reported to stimulate germination of seed. Because of its polyphenolic structure it is reported to be useful for the preparation of certain pharmaceuticals and in the field of plastics and drying oils. It has also been proposed as an antioxidant in non-edible products such as petroleum and rubber goods.

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2. COTTONSEED AND ITS PRODUCTS

By

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Well-covered, well-draughted, cement-floored seed storage is essential in India. Use of manganese borate (5 lb./acre) or castor cake (40-50 lb./acre) increased oil content in pot-culture experiments. Free fatty acids may be removed under vacuum, and subsequent refining losses are very small. If crude oil is treated with alkali continuously as it emerges, rise in F.F.A. on subsequent storage can be avoided. Short-time hydrogenation of oil with only a trace of catalyst greatly reduces oil colour and renders bleaching unnecessary. A solvent-extracted oil of very light colour has been produced. Delinting by chemical methods should be considered. The pitch from acidulated soapstock distillation can be processed to a high-gloss graphite.

Storage of Seed

Some sixteen years ago, when I paid a visit to Hyderabad-Sind, to-day a part of West Pakistan, I had occasion to visit a factory owned by Messrs. Gobindram Seksaria, a well-known industrialist, which included delinting and refining, and processed 15 tons of cottonseed per day. Bags of cottonseed were lying in the open. In my ignorance and comparative inexperience, I asked what seemed a sensible question, as to how they could afford to let seeds be thus exposed to weather. Mr. Mansukha, the Manager, smilingly asked me if I knew the rainfall there. Three inches per annum, he said, and once about 7 inches and considered a deluge! In such desert areas, the question of covered space did not arise. But in other areas processing cottonseed, the annual rainfall is not usually as low as 3-7 inches. Heat by itself, even 117°F in the shade, should not materially affect seed-quality, but moisture definitely does. If there is both heat and moisture, the expressed oil has a high F.F.A. In India, with which this symposium is primarily concerned, large mills should have well-covered seed storage space whatever the seed, cottonseed being no exception. Costly silos can be thought of only if finance is not a consideration. However, well-draughted, cement-floored storage is essential.

Seed Varieties and Oil Content

The seeds I saw there as well as in Lahore were American-Uplands, as they were then styled, of lint content 2-3%. In India there are of course many types. Besides American varieties, there are Cambodias, Sea-Island, *Desi*, Oomras, Hubli, Parbhani,etc.; there are long-staple, short-staple, high-fuzz, low-fuzz, high-oil, low-oil, and so on. There are dark-skinned and chestnut-coloured seeds. The oil content ranges from 17-22%, but is mostly below 19%.

In pot-cultures of about half-an-acre, I have found that the oil content could be increased from 17% to 19-20% by a small dose of manganese borate to the soil at the rate of 5 lbs. an acre. Whether this will be so in all areas I cannot assert. The use of castor cake as manure, to the extent of about 40-50 lb. an acre before planting, was found to be almost equally fruitful in giving a larger cotton yield as well as seeds of higher oil-content.

Refining of Oil

Refining of crude cottonseed oil was once a most jealously-guarded secret. It was not merely losses in removal of free fatty acids that occurred, but loss of oil as such also. B. Kishenlal and Dayaram Surajmal Lahoti were the pioneers in attempting cottonseed crushing successfully in the former Hyderabad state. Today many are doing it in a small or a large way, and the chemist or operator-in-charge has acquired so much proficiency that oils now exported from India have an F.F.A. seldom above 0.2% and very satisfactory colour. But I have not seen an oil like those I saw produced in Pakistan. Alkali of strength 10.20° Beaume was usually used, the excess over the theoretical needed to get the correct "break" being a matter for the man-in-charge to decide by experience. Colour was bleached by acid-clays like Tonsil or 711 ICI brands.

In Lahore, at the Punjab Oil & General Mills Ltd., then managed by Zahur Ahmed & Sons, ignorant Pathans were trained to carry out alkali-washing of raw cottonseed oil in *kadais* (pans) on an open fire with most satisfactory results.

Fatty acids are steam-volatile, the more so under vacuum. I have successfully applied this technique to crude oil, and have alkali-treated the almost acid-free oil thereafter, with the result that the oil-loss was almost theoretical and not, as is usual, double the theoretical. In the old days of alkali-treatment, raw oil lost as soap-stock was 15-18%! The volatile fatty acids were collected in a well below the barometric condenser, and used for soap-making as usual. The separation of the soapstock from an alkali-treated cottonseed oil is very clear-cut unlike the soapstock break in many other oils. Crude or raw cottonseed oil is allowed to accumulate in appreciable quantity before being batch-refined; during this period it rises in F.F.A. owing to the presence of protein residues and lipoclastic bodies. Hence, I adopted a sort of continuous alkali-treatment as soon as oil started oozing out of expellers; as a result, the alkali-washed oil was paler and the loss in refining almost theoretical as F.F.A. had not increased much.

Hydrogenation

Carefully pre-neutralised and washed, soap-free oil presents little difficulty in hydrogenation to any degree of hardness, even to an iodine value of 2, yielding a pale cream, brittle solid of excellent keeping qualities. But, by partial hydrogenation selectively and with only a trace of catalyst for a very short time, bringing about a reduction in iodine absorption of only 1 or 2 units, the colour could be made very pale thus doing away with the need for using Fuller's earth of foreign origin. Indian earths are still not comparable with foreign products, even though many papers have been published about activation of bentonite, diatoms, etc.

Acid-free (even unhydrogenated) oil is a fine soap material. The lather is of a high order: the titre of the mixed fatty acids is about 34°C while that of coconut mixed fatty acids is about 23°C. Cotton soap is thus somewhat harder than that from the latter.

Solvent Extraction

The firm of Anderson, U.S.A., well-known for their expellers, has many commendable features in their plant, but from my limited experience almost every plant or process gives about the same results. Here also I have tried to get a crude oil of very pale colour. I cannot divulge the actual method, which is perhaps a matter for patent, but I can assure you that I have in the laboratory produced an oil by extraction, which without alkali treatment was of the colour of crude groundnut expeller oil. I have moved the Central Government to give me a grant to conduct further research, and I hope this will succeed. Solvent extraction is almost a by-word now in industrial circles. If the equipment for solvent recovery is fool-proof, there is no need for a costly technician to be in charge, a sensible mistry would suffice. There is little chemistry in a leaching-out operation.

In place of costly foreign plants, locally-improvised plants could do as well, if carefully designed. I learn that Shri P. K. Kurup, a Chemical Engineer well-known in Hyderabad and Bombay, is now designing several small pilot-plants of a semi-commercial nature, but economically profitable to small investors.

It need hardly be mentioned that the refined oil is a fine edible oil and also good for soap. The hardened oil can be a source of stearic and oleic acids.

Fundamental Studies

This comprises both chemical and trade matters. Cottonseed oil is sometimes cheaper than groundnut oil, and sometimes dearer. One has therefore to be on the watch to decide whether to crush cottonseed or not, to delint it or not, etc. Indian cottonseed is largely available as India produces, consumes and exports a huge quantity of cotton bales. The old habit of feeding cattle with high-lint seed needs to be discouraged by legislation; it is positively harmful to cattle. Lint removal may sometimes not pay because of the labour costs involved. Some solution must be found for that by all concerned. Delinting by methods other than mechanical is what I have in view. I have successfully removed the entire lint leaving a clean, chestnut-coloured seed by a process which I have yet to perfect on a large scale, small-scale experiments being most satisfactory with one type, but not with the soft, darker-skinned seed.

By–products

The by-product in oil refining is soapstock Cottonseed oil soapstock, as usually obtained from the neutralising pan, has a fatty content of about 55% unless thinned out deliberately. It is dark outside, but may be orangish inside when the outer skin is removed, of an evil smell and discolouring all cloth coming in contact with its colouring matter, which scientists are attempting to recover. When this soapstock is fully saponified and "cut" with alkali or salt, even after 4-5 such operations the 'neat' soap obtained is brownish black, and not fit for use in high-grade soaps as such. But, if instead of completely saponifying, it is subjected to vacuum distillation, after Twitchelling for full release of fatty acids, very pale-coloured fatty acids suitable for toilet soaps could be got. Such fatty acids is often cream-coloured, depending on the vacuum available and plant refinement.

The non-volatile pitch residue could be used as an electrical insulator. But, by a suitable treatment, a fine high-gloss graphite excelling the natural product and of an unbelievably light colour has been prepared by me. Samples have been taken by so many parties that I have nothing left with me while the plant that I worked with is far away in Gujerat. I am however trying to get them to send me some at an early date.

Standards

Most of the Standards set up by the Indian Standards Institution have been almost all been modelled on British Standard Specifications, *mutatis mutandis*. For internal use we could draw up a sub-standard inferred from the U.S.A. or B.S.S. specification. But when the talk is now of difficult foreign exchange, hard currency and of earning more foreign currency, it is better to fall in line with international standards if we have to raise our heads as a country that counts in world trade. Standards could and must be adhered to, but Government, in the hands of those inexperienced in trade or commerce or the ways of economy, go on imposing so many export duties, cesses, excise duties, and other vexations that industrialist are loath to embark on new and fundamentally-profitable lines.

Marketing data are the subject of specialists but the competent chemist can content himself with the solace that within his power he has tried to put into practice what he has gleaned from books, both theoretical and technical, written in good language by foreign specialists grudging little of trade secrets.

3. STUDIES ON THE PREPARATION OF CHEMICAL COTTON

By

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Choice of linter cuts is important for processing; for chemical cotton production, "second-cuts" are preferred. Details are given of experimental work done to process Indian linters to chemical cotton of good quality.

Introduction

Cotton linters are one of the main sources of pure cellulose for regenerative purposes. After proper treatment these can furnish cellulose with an α-cellulose content of as much as 99.8%. The cellulose so obtained is generally called chemical cotton and is an industrial intermediate for the production of commercially important cellulose esters and ethers which find use in the plastics, lacquers, explosives and textile industries.

This paper summarises the results of experiments carried out in this laboratory with the object of establishing conditions for the preparation of chemical cotton of different grades.

Choice of Linter Type and Requirement

It is important that the proper type of linters are selected keeping the end product in view. Rao and Chari[1] have emphasised the need for grading of linters; here it will just be mentioned that grading depends on fibre length, colour, yield of cellulose and contaminants. For chemical cotton, the "first-cut" linters are not suitable because of their fibre length of 6-12 mm., and the chemical cotton obtained from these is not as reactive as that from "second-cut" linters (2-3 mm. fibre length) or from "mill-run" linters (3-8 mm. fibre length). In the latter fibre types the reagent used for esterification or etherification can penetrate the chemical cotton better due to shorter fibre length. With "first-cut" linters it may not be possible easily to take such reactions to completion.

Besides staple, several other factors influence the choice of linters for processing to chemical cotton. These are:

1. The percentage of gross contaminants like dust, trash and seed particles, and the yield of lint on Shirley analyses, which should be not less than about 60%.

2. The ash content, the ether- and benzene-soluble matter and the percentage of α-cellulose after refining.

If the chemical cotton is to be converted into rayon it is best to start with linters low in ash and iron content. If it is to be used for cellulose nitrate, for example, a higher ash content is permissible and iron content is not so critical.

STAGES IN THE PRODUCTION OF CHEMICAL COTTON

Precleaning

Mechanical precleaning is designed to reduce gross impurities. Since a pre-cleaning unit is under fabrication; in experimental work reported here seeds were cleaned manually.

Digestion with Caustic Soda Solution

This is meant to remove mainly lignin, wax, pectin, and polyanhydroglucoses of low degrees of polymerisation. It is a crucial step and requires careful control of (1) concentration of the alkali, (2) proportion of alkali to linters, (3) pressure of digestion, and (4) time of digestion. The viscosity of the end-product is decided here. Air has to be excluded, otherwise considerable oxidative degradation would take place. Cellulose acetate and carboxymethyl cellulose, for example, require high-viscosity chemical cotton. Cellulose nitrate for use as a propellant needs medium-viscosity chemical cotton and that for use in lacquers requires low-viscosity chemical cotton. Such viscosity requirements are tabulated below in terms of the modified A.C.S. Method with 20 cm. beadfall:

For:	Cellulose acetate	Cellulose ethers	Cellulose nitrate explosives	Cellulose nitrate lacquers	Viscose
Viscosity	400-650	...	46-165	25-45	12-16

By using milder conditions during digestion high-viscosity products are obtained and by using more vigorous conditions the viscosity goes down. The yield of air-dry digested linters from various Indian sources varies between 70-80%. The digesters used may be of the stationary or the rotary types. In earlier experiments in this laboratory a stationary digester was used. This had the disadvantage that the product was not uniform and samples from the top, middle and the bottom of the digester had very different viscosities, the bottom portions being of very low viscosity; *e.g.*, the results of one experiment were:

Raw linters g.	3% NaOH used, ml.	Pressure p.s.i.	Time, hr.	Air-dry yield, g.	Viscosity		
					Top	Middle	Bottom
100	500	70	4	81	190	65	30

In industrial practice stationary digesters can be used but these must then have a forced circulation of pre-heated alkali to ensure a uniform product.

Subsequent experiments in the laboratory were conducted in a rotary digester fabricated of stainless steel and heated with steam. Results were much better and a fairly uniform product was obtained.

The material of construction may be mild steel if the iron content in the final chemical cotton is not critical. This adds to the iron content of the linters. Linters with an initial iron content of 200-300 p.p.m. were found to have as much as 800 p.p.m. of iron after digestion in a mild steel rotary digester.

The amount of caustic soda actually utilised during the digestion varied with the quality of linters. No experiments on the recovery of caustic soda were carried out. It was generally found that if 15 g. of caustic soda is taken per 100 gms. of linters only about 40-50% of this is utilised. It may be worthwhile to recover it from the black liquor by the usual processes.

Reducing the Ash Content

Experiments were conducted using dilute sulphuric acid in different concentrations for washing the linters to reduce ash content. This souring was also carried out with dilute hydrochloric and nitric acids at comparative concentrations. The efficiency of the three acids did not show significant variation in preliminary experiments and sulphuric acid, being the cheapest, was thereafter used for more extensive trials.

It was found that souring with 5-6% of sulphuric acid on the weight of linters after digestion, reduced the ash content from about 1-1.5% to 0.2-0.25%. About half of this ash was accounted to silica which could be removed only mechanically. Ultimately it was found possible to get chemical cotton with an ash content of 0.1% or less.

Deironing

By treatment with oxalic acid it was found possible to reduce the iron content of the linters to about 50-60 p.p.m. from an initial content of 200-300 p.p.m. Usually 5% of oxalic acid on the weight of linters in a 0.5% solution was used for this purpose for an hour. High concentrations of oxalic acid and more time did not further lower the iron content significantly.

Bleaching

This was studied with digested linters before souring and deironing and also after these stages. Better shades with less consumption of hypochlorite were obtained if souring and deironing were carried out before bleaching.

Bleaching was studied with hydrogen peroxide and sodium hypochlorite. Hydrogen peroxide led to products with lower viscosities. The hypochlorite method yielded high-viscosity products. The effect of time on utilisation of chlorine and fall of viscosity was studied and the results shown that bleaching is complete usually within 30 minutes. The fall in viscosity takes place during the first fifteen minutes.

A typical progressive analysis is shown below:

	Raw Precleaned	Digested	Soured	Deironed and bleached
Ash %	2.54	1.188	0.254	0.09
$S_i O_2$ %	0.484	0.326	0.116	0.075
Iron p.p.m.	700	600	350	60-160
Ether-soluble matter %	1.844	0.154	...	0.13
Lignins %	6.16	1.66	...	...
Oxycellulose %	17.3	2.10	...	1-1.5
$\propto$-cellulose %		96.7	...	98-99
Viscosity (A.C.S.)		1000	750	300

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4. UTILISATION OF COTTONSEED OIL–REFINING FOOTS

By

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1500-3000 tons of foots annually produced in cottonseed oil refining constitute at present a waste product in India. Foots contained 56-83% of total fatty acids and from 2-42% of neutral oil (on a dry basis); oxidised fatty matter comprised 5-38% of the total fatty acids. The remaining fatty acids consisted of 21% saturated, 48% oleic and 31% linoleic acids. Sufficient alkali for hydrolysis is usually present in foots, and dilution with their own weight of water and heating for 6-7 hr. at 100-110 p.s.i. gives complete hydrolysis; distillation after acidulation and drying yielded 70.8% of fatty acids (on total fatty acids present) leaving stearing pitch. By application of the urea adduct technique, 82-88% of the fatty acids were recovered as a light-coloured material in two crops of I.V. 57-87 and 122-151 respectively.

Dry foots-lime mixtures on pyrolysis gave a 21% yield of crude oil, which could be fractionally distilled to gasoline (31-35%) and kerosene (43-50%).

Introduction

The soapstock or foots resulting from alkali-refining of oils are generally used in India for soapmaking. The foots from cottonseed oil, however, are very dark, and even repeated salting-out does not reduce the colour appreciably, and involves considerable soap losses. Except for the manufacture of a small quantity of cheap laundry soap, the foots are at present a waste product of the cottonseed oil refining industry, generally dumped in the open where they putrefy and desiccate.

Of the estimated total production of 1.7 million tons of cottonseed (1956-57),[1] only about 6% is at present crushed,[2] thus yielding over 10,000 tons of oil. On alkali refining, this oil is estimated to give annually 1,500 to 3,000 tons of foots. With the projected increase in the crushing capacity during the Second Plan period (1956-61), the production of the oil, and consequently, of by-product foots, is likely to increase three-fold by 1961.

Cottonseed oil foots contain potentially valuable fatty acids. A process for their recovery or utilisation would be of interest to industry. Analyses of various commercial samples of foots from Indian cottonseed oil carried out by different workers are given in Table I.[3-7] Since the quantity of water present in the foots is entirely dependent on the strength of alkali used in the refining process and wash water employed subsequently, it varies within wide limits (17-40%) in the foots. To enable a more rational comparison of the various foots analysed, the tabulated results have been calculated on a dry basis. Harwalkar, Achaya and Saletore[5] have further studied the total fatty acids obtained from a sample of foots by ester fractionation of the mainly saturated (18.4%; I.V. 34.1) and the mainly unsaturated group (81.6%; I.V. 111.7) obtained by lead salt separation. The results of their analysis are given in Table II.

TABLE I

Composition of Indian Cottonseed Oil Foots[a]

% wt.	Bhushan *et al.*[3]	Harwalkar *et al.*[5]	Subrahmanyam[6]	Rao[7]
Total fatty acids	82.8	56.4	60.9	66.7
Neutral oil	42.5 (Calc. from glycerine)	11 3	13.1	2.5
Free acids (by diff.)	40.3	45.1	47.8	64.2
Oxidised fatty matter[b]	...	...	...	14.0
Total alkali (as Na_2O)	4.2	...	...	...
Foreign organic matter	4.4	.	...	...
Glycerine	4.6	...	...	..
Inorganic salts	3.1	...	...	...

(*a*) Calculated on a dry basis. Moisture in the original samples amounted to 20.6, 17.2, 21.3 and 40.0% respectively.

(*b*) Achaya *et al.*[12] have shown that oxidised fatty matter varies from 5-38% of total fatty acids, which themselves vary from 40-66% of the foots as obtained.

TABLE II

Composition of Fatty Acids From Indian Cottonseed Oil Foots[5]

Fatty acid, % wt.	Foots	Cottonseed oil (high-oleic type)	Cottonseed oil (high-linoleic type)
Myristic	1.1	1.3	2.3
Palmitic	18.2	17.1	19.5
Stearic	1.6	2.0	0.9
Hexadecenoic	...	1.3	0.8
Oleic	48.4	41.4	34.8
Linoleic	30.7	36.9	41.7

Keith, Blachly and Sadler[8,9] have described a method for alkali refining of cottonseed oil foots. The soapstock is treated with 5-10% lye when most of the impurities are dissolved and the grained fatty matter is separated centrifugally. Recovery of the fatty acids by this method is reported to be higher than by other methods. However, in commercial practice in the U.S.A. saponification followed by distillation under reduced pressure or with superheated steam is usually employed to recover light-coloured fatty acids from foots.[10]

This procedure was applied to Indian foots by Bhushan, Phillips and Gulati.[3] Achaya, Baliga, Saletore and Zaheer[11,12] evolved an alternative procedure which does not involve distillation; By employing the urea adduct-formation technique whereby urea rejects polymeric colouring and fatty materials, the mixed fatty acid urea adducts after separation are decomposed to give pale fatty acids in two crops.

This paper reports the results of our investigations on the recovery of fatty acids from Indian cottonseed oil foots by the usual distillation methods and by the urea adduct technique. The paper also describes experiments on the pyrolysis of foots with a view to obtaining synthetic liquid fuel;[4] similar work had earlier been reported by Chinese workers.[13-15]

EXPERIMENTAL PROCEDURE

A. Recovery of Fatty Acids

1. *Distillation method.* Preliminary experiments indicated that the pressure hydrolysis of foots yields dark products difficult to analyse and fractionate. Also, the soap present in the foots was enough to catalyse the hydrolysis and no additional alkali was required. Data were, therefore, obtained by hydrolysis of 'artificial' foots prepared by saponifying commercial (semi-refined) cottonseed oil with caustic soda in quantity enough to conform to the composition of the available foots.[3]

Ten samples of artificially-prepared foots (each from 600 g. cottonseed oil, 36 g. caustic soda and diluted with different volumes of water) were subjected to hydrolysis at 100-110 p.s.i. in an autoclave of 6-litre capacity for 6-12 hr. After cooling, the reaction mixture (emulsion) was boiled with excess dilute sulphuric acid, and the fatty acid layer separated and dried after washing it free of mineral acid.

From the results given in Table III, it can be inferred that for complete hydrolysis, the foots, which already contain 20.6% water,[3] should be further diluted with their own weight of water and heated for 6-7 hr. at 100-110 p.s.i.

TABLE III

Hydrolysis of Artificial Foots at 100-110 p.s.i.*

Expt.	Water in emulsion, %	Time, hr.	Acid value
1	60	12	197
2	60	8	198
3	60	7	198
4	60	6	196
5	60	4	174
6	50	6	195
7+	45	6	188
8+	40	6	183
9+	30	6	179
10++	50	6	180

*Pressures higher than 110 p.s.i. lead to hydrocarbon formation. + Charring took place.
++ Hydrolysis at 90-100 p.s.i.

The foots (3 kg.) were hydrolysed under the optimum conditions described above and the fatty acids that separated were dried at 150°C. The dark viscous mass thus obtained was twice distilled with superheated steam (240-260°C) at 400-420 mm. pressure to give light-coloured fatty acids (acid value 198; yield 1.4 kg. or 70.8% on weight of total fatty acids and 46.9% on weight of foots used).

The residue (0.77 kg.; 25.6% on weight of foots) left after the first distillation was dark-green, brittle, shining stearine pitch (acid value 10; softening temp. above 200°C; matter insoluble in ether-alcohol, 69.9%; free carbon, 35.0%; soft asphalt, traces). Hard stearine pitch is used for caulking of ship decks, as insulating material, for waterproofing, and for making varnishes and anti-rust paints. The softer variety is used as lubricant for heavy steel plate rollers.

In another laboratory experiment,[7] cottonseed oil foots, which already contained 40% water, were further diluted with 3 times their weight of water and boiled after adding sodium hydroxide (2% on the weight of foots). The liberated mixed fatty acids were distilled at 2-3 mm. pressure when the fatty acids were recovered at 230-240°C in a yield of 62.0%.

2. *Urea-adduct method.* Foots from expeller cottonseed oil (original free acidity of crude oil, 2% oleic acid), refined in the laboratory by the standard A.O.C.S. procedure,[16] were used for standardizing the procedure. Excess alkali and some alcohol were added, the foots completely saponified under reflux, the fatty acids liberated by acidulation and washed by boiling repeatedly with water. Finally, the acids were dried with sodium sulphate. Total fatty acids were obtained in this way from the foots from the other sources also studied later.

A mixture of crude fatty acids (1 part), urea (4 parts, determined optimum) and 95% ethanol (5 parts) was refluxed for 30 min. and cooled overnight. The adduct was filtered under section, washed with ethanol and fatty acids liberated by boiling the adduct with water (slightly acidulated if urea recovery is not contemplated). The liberated acids were isolated employing ether and comprised the first crop of fatty acids.

The ethanolic filtrate was then immersed in a water bath for about 30 min. so that as much alcohol as possible boiled away. The residual mass was broken up with the help of ethanol and filtered to yield the second crop of adducts from which fatty acids were recovered.

For analytical purposes, the recovered alcohol-solubles were repeatedly boiled with light petroleum to remove any residual monomeric fatty acids. A shiny, greenish, brittle pitch was left behind.

All the products were analysed (*vide* Table IV). The first crop (36-77%) constituted fatty acids of low unsaturation (I.V. 57-87), while the second crop (5-15%) had a much higher iodine value (120-150). The pitch comprised 5-37.9%. The total recovery of fatty acids adds up to 51-85% on the weight of crude total fatty acids or 82-89% by weight of the monomeric fatty acids present in the crude stock.

TABLE IV

Urea-precipitation of Fatty Acids From Cottonseed Oil Foots

Fatty acids from refining foots of	Parts of urea	Acids from first urea p.p.t.		Acids from second urea p.p.t.		Unrecovered monomers		Polymers (petroleum ether insoluble %)	Monomers present, %	Monomers recovered, % of those present
		%	I.V.	%	I.V.	%	I.V.			
1. Expeller oil (original acidity 2.0% oleic), laboratory refined. ...	6	35.9	57.0	15.2	132.2	11.0	...	37.9	62.0	82.3
2. Different oils, laboratory refined, mixed foots. ...	6	68.0	86.9	8.9	132.1	10.4	120.4	12.7	87.3	88.1
3. Expeller oil (original acidity 7.0 % oleic), laboratory refined. ...	4	75.8	87.5	8.8	151.0	10.4	131.4	5.0	95.0	89.1
4. Expeller oil, commercially refined, foots 6 months old & slightly mouldy. ...	6	56.4	82.8	8.0	128.6	10.7	134.8	24.9	75.1	85.8
5. do	4	60.6	71.2	5.2	122.0	8.7	124.0	25.5	74.5	88.3

The application of the above procedure on various samples of cottonseed oil foots resulted in working losses of the order of only 1-2%. Though urea adducts are known to be formed even in the absence of solvents, the use of ethanol facilitates filtration, prevents the adduct setting into a hard mass and perhaps enhances adduct formation by increasing the fluidity of the mixture. In commercial practice, the solvent can be recovered without appreciable loss.

The 82-88% recoveries of fatty acids by this method is comparable to that in commercial distillation. Moreover, the fatty acids are recovered in two distinct fractions; the low iodine value fraction could be used in soap making and the other in alkyd manufacture. Further resolution of each fraction can be effected if desired by the urea-resolution technique described by Achaya, Baliga, Saletore and Zaheer.[17,18]

The pitch appeared to be similar to material obtained by the distillation method. It was characterised by its almost complete solubility in alcohol and was not studied further. Since no distillation was involved in the present urea-adduct method, it follows that a large quantity of pitch is apparently produced during the refining operation itself and not, as generally believed, during the subsequent distillation. In the present study, the true polymeric pitch was isolated each time for the purpose of estimation by its insolubility in petroleum ether. In applying this method on a large scale, the pitch would be obtained admixed with 10% of unrecovered unsaturated monomeric fatty acids.

B. Pyrolysis of Foots

Reaction mixtures were prepared by heating to dryness 100 g. of foots[4] with milk of lime containing 10, 15 and 20 g. of lime (CaO, 60%); in each case a dark green brittle solid was obtained on cooling. The reaction mixtures were pyrolysed after pulverisation in an apparatus described by Joshi, Gulati and Bhushan.[19] All the mixtures gave crude oil (16-21%). Optimum conditions for pyrolysis are to heat the pulverised mixture (lime, 80 mesh; 15-20% on weight of foots) at 450-80°C when crude oil is obtained in 21% yield.

Calcium and sodium soaps prepared from refined cottonseed oil on pyrolysis, under the conditions described above, also gave crude oil in 84 and 82% yield respectively; both these oils on standing deposited a wax (yield 18%; acid value 1.0) which was not examined further.

The crude oils obtained by the pyrolysis of foots-lime mixture or of calcium and sodium soaps of refined cottonseed oil (after dewaxing) were similar in character (acid value, 1.0; sap. val., nil; cal. val., 17,400 BTU/lb; d_{25}^{25}, 0.82—0.83). On distillation, 31-35% gasoline and 43-50% kerosene fractions were obtained. Distillation ranges of some typical samples are given in Table V.

TABLE V

Distillation of Crude Oil and Gasoline

Temp., °C		Distillate, %			
		Crude oil			Gasoline from foots
		Foots-lime mixture	Calcium soap	Sodium soap	
70	Gasoline	Traces	Traces	Traces	Traces
100		–	6	6	2
125		8	12	12	14
150		15	20	22	32
175		23	30	31	50
200		31	35	35	68
225	Kerosene	42	42	42	82
240		47	49	49	89
275		61	62	62	92
300		71	71	72	97
325		81	78	79	...
350	Heavy oil	89	87	88	...
	Residue	11	13	12	...

The crude oil fraction boiling upto 200°C was separated as gasoline and analysed to: I.V. 50; d_{25}^{25} 0.7914; cal. val. not determined accurately but rated higher than 19,000 BTU/lb. The corresponding value for kerosene fraction (b.p. 225-325°C) is 19,200 BTU/lb. Freshly-distilled gasoline was colourless and pleasant-smelling. In keeping, however, it deteriorated to a dark brown colour. By shaking with 2% commercial sulphuric acid and subsequent steam-distillation, it could be stabilised for 6 weeks.

The nature of combustible gases was not studied nor was the residue left on cracking examined in detail. Sodium carbonate (70% purity) was recoverd from the latter.

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5. PROCESSING OF COTTONSEED OIL SOAPSTOCK

By

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After reviewing the various possibilities of processing cottonseed oil soapstock, experimental work is described on analysis of soapstock, bleaching with H_2O_2, NaOCl and $NaClO_2$, solvent treatment, repeated alkali-graining, separation through urea adducts, and fatty acid distillation on a laboratory scale and through a small fabricated stainless-steel unit of 10 lb. capacity. Alkali-graining and distillation of fatty acids are shown to be effective, but the former would be expensive.

Introduction

The present annual production of cottonseed oil in India is between 15 and 20,000 tons. It is well-known that for the raw cottonseed oil to be made useful for any purpose, it must receive an alkali treatment. The inevitable product of this treatment is soapstock, which on account of its deep black colour has always proved a disposal problem. The present annual production of cottonseed oil soapstock is estimated at 1000 tons and this is bound to increase as larger quantities of cottonseed oil find application in the manufacture of refined oil, vanaspati and soap. Naturally for cottonseed oil refining to be economic, the soapstock must fetch some value proportionate to the loss of cottonseed oil in refining.

In Europe and the U.S.A., where large quantities of cottonseed oil are being refined, the disposal of the soapstock is done in three different ways, as indicated by Bailey,[1] *viz*:

(i) Entire soap base for highly alkaline washing powders;

(ii) In conjunction with other soap bases, in manufacture of highly-built household powdered soap and yellow bar laundry soap;

(iii) Processed in fatty acid distillation plants for recovery of fatty acids and pitch.

It appears that in this country, small portions of the soapstock are being used in the manufacture of cheap black *dhobi* soap. Alkali-graining of the completely saponified soapstock is also being followed in some cottonseed oil mills. Actual details of the process are, however, lacking.

Literature Survey

Wesson[2] in 1907 was probably the first to draw attention to a better utilization of cottonseed oil soapstock, by alkali saponification followed by repeated washings of the "killed foots" with small excess of caustic alkali each time. Since Wesson's time, the soapstock has been investigated by several workers. The available information is reviewed here.

Composition

The value of soapstock is determined by its content of fatty matter, which varies considerably depending on the method of refining the cottonseed oil. Soapstock is mainly composed of free neutral oil, water and soap. Analytical values of a few samples as reported in the literature are given in Table I.

TABLE I

Analytical Values for Cottonseed Oil Soapstock

Per cent	Sample Number				
	1	2a	3b	4	5
Moisture	36.0	20.6	45.6	...	...
Fatty matter	50.0	66.2	24.0 (as soap)	45-58	25-35
Free alkali as Na_2O	3.2	3.3	3.3	...	...
Organic matter	8.2	3.5	8.0	...	...
Glycerine	3.98	3.7	...	...	...
Insoluble impurities	...	..	...	1.6-3.3	2.0-4.7
Oxidized acids	...	...	...	0.9-1.7	0.6-2.3
Reference No.	2	3	4	5	5

(*a*) Inorganic salts 2.45%. (*b*) Neutral oil 18.0%.

Refining of the Soapstock by Means of Alkali

Most of the impurities present in the soapstock are soluble in caustic lye. The soapstock is first treated with a slight excess of caustic lye (on the basis of the neutral oil content of the soapstock) to ensure complete saponification. The soap so formed is repeatedly grained out with caustic soda solution. The colouring matter is also soluble in dilute salt solutions. Strong brine, however, renders it insoluble. The lye from the saponification charge carries the bulk of the organic and colouring matter with it. Proper washing of the cottonseed oil soapstock requires considerable care and experience.

The most recent work on alkali-refining of soapstock is by Keith and coworkers.[5] They found that a slight excess of caustic above that necessary for complete saponification of neutral oil did not prove effective in removing impurities. Gums were found to be dissolved in the lye of the grained soap, when the caustic concentration of the lye was 5 to 10%. Under these conditions, a soap phase of 45-60% total fatty matter could be centrifugally separated and most of the impurities were discharged as lye. The amount of oxidized acids and other ether-insoluble impurities had also decreased considerably. Laboratory distillation of alkali-treated soapstock fatty acids showed that a yield of 86-89% could be obtained as against 69-70% from untreated stocks.

In a subsequent paper, Keith and coworkers[6] have described an equipment layout for continuous purification and acidulation of soapstock. The soapstock and caustic solutions were continuously mixed and centrifuged, grained further with salt and centrifuged. At 175-195°F in the presence of dispersing agents, using spent acid containing about 4%

H_2SO_4, acidulation of purified soapstock yielded a clean brown fatty acid phase, with acid value about 188, unsaponifiable matter 3% and oxidized acid content 3-5%.

Bleaching of the Soapstock or Acid Oil

Hydrogen peroxide, sodium hypochlorite, and sodium chlorite have been found to be the most suitable bleaching agents for soapstock.

Ya Samarin and Gurevich[7] mixed the grained soapstock with 10-15% solution of H_2O_2 (3-8% of 30% H_2O_2 per ton) in a mechanical blender and allowed it to settle for 1.0 to 1.5 hours. The lye underneath the soap was withdrawn and after washing, the soap had a light colour.

C. Paquot and M. Paquot[8] found that $SnCl_2$ acted better than H_3PO_4 or persulphates as activator in bleaching with $NaClO_2$. An aqueous solution of $SnCl_2$ was added to the soapstock at 80°C under agitation. This was immediately followed by a 10% aqueous solution of $NaClO_2$. The bleaching effect was found to be very significant in 10-15 minutes, with 0.6-1.0% $SnCl_2$ and 0.3-0.4% of $NaClO_2$.There was some simultaneous deodorization also.

Two patented processes recommend also the use of chlorite and hypochlorite. In one,[9] the bleaching is carried out in one of the three following ways:

(i) the chlorite and hypochlorite are mixed before addition to the soapstock;

(ii) chlorite is added before the hypochlorite, and

(iii) the chlorite and/or hypochlorite are formed *in situ* in the soapstocks.

The amount of chlorite is 0.1 to 10% and that of hypochlorite 0.02 to 3.0%. The temperature of bleaching is 40-100°C.

The other patent[10] uses solutions of alkali metal or alkali earth chlorites, together with phosphoric acid and/or phosphates in the presence of other acids and/or acid phosphates.

Urea Adducts of Raw Fatty Acids[11]

Formation of crystalline adducts of fatty acids with solid urea in the presence of ethanol has been employed for two-stage recovery of pale-coloured fatty acids from dark cottonseed oil soapstock fatty acids. The process essentially consists in refluxing a mixture of crude dark-coloured fatty acids from the soapstock, urea (2 to 4 parts) and 95% ethanol (5 parts) and cooling overnight. The mixture is then filtered under suction and the precipitate washed repeatedly with ethanol till the washings are colourless. Both the precipitate and alcohol-solubles (from which the alcohol is previously removed) are boiled with water and the liberated fatty acids extracted with ether. Total recovery was found to be over 80%. There were two distinct fractions, one with a low I.V. (57-87) and the other with a high I.V. (122-151). The pitch left behind was a dark-green, sticky or brittle mass.

Dry Distillation of the Soapstock

Chang-Ming Tu and Fu-Yun Pan[12] distilled the soapstock without a vapour-phase cracking unit, and obtained a product consisting (by wt.) of 11% light oil, 17% middle oil and 10% heavy oil. Insertion of a cracking unit increased slightly the amount of light and middle oils at the expense of heavy oil and produced more gaseous compounds.

Yung-Sheng Chao[13] dry-distilled the soapstock and obtained a gasoline substitute among other products. This gasoline was essentially the same as commercial gasoline, except for its odour and high iodine value. Very satisfactory results were obtained in actual road rests. From 400 lb. of original wet soapstock, 5 gallons of refined gasoline, 7.3 gallons of crude kerosene, 77.8 lb. of coke, 31.5 lb. of Na_2CO_3, 13.2 lb. of ammonia liquor and 489 cu. ft. of combustible gas could be obtained.

Distillation of Fatty Acids

Fatty acid distillation has now become a standard unit operation in fat technology and it has enabled upgrading of low-quality fatty material like waste fats and dark-coloured soapstocks. Berger[14] and Potts[15] have described in great detail the design, features and operating data of fatty acid distillation, while patents by Bamag Ltd.,[16] McClain,[17] Stevens[18] and Hoffman[19] deal with the distillation of soapstock fatty acids.

Distillation of such acids leaves behind a black, brittle pitch (stearine pitch), which is recommended for use in the manufacture of inks, paints and varnishes and for brake-lining.[20] Paschke *et al.*[21] have conducted some experiments for conditioning of agricultural soils with still pitch, a soil conditioner being a material which improves the tilth and water holding capacity of soils. Vegetable pitch (I.V. 93, A.V. 15, S.V. 120, unsaponifiable matter 25%, nitrogen 0.4%, ash 0.6%) containing polymerized and partly esterified fatty acids, hydrocarbons, polyketones, etc. was taken in ethyl ether, mixed with clay and the solvent then removed. Upto 98% of Boston blue clay was converted to water-soluble aggregates by 4% of pitch. The cost was estimated to be only 15% of that using synthetic polyelectrolytes for the same purpose.

Miscellaneous

Pack and Goldblatt[22] have attempted to find new outlets for soapstock.

(i) The soapstock dried by azeotropic distillation was refluxed with benzyl chloride for 2-4 hours, the resulting mixture was filtered while warm and the filtrate was distilled. Crude benzyl, methyl benzyl and dimethyl benzyl esters were thus formed. These were, however, found unsuitable as primary plasticizers.

(ii) Acidulated soapstocks added in small quantities (0.5 to 2.0%) to dry meals (for cattle feeds) keeps the dust down and aids the pelleting operation. It is, however, necessary that gossypol be destroyed before incorporation, and this was achieved by heating the dilute soapstock out of contact with air. Alkaline soapstock was found to be far easier to free from gossypol than acidulated soapstocks.

A method for separating solid and liquid fatty acids from soapstocks has been patented by Canada Packers.[23] It is claimed that in aqueous medium, when fatty acids are specially treated, enrichment of the more unsaturated and shorter chain fatty acids occurs in the mother liquor. Cottonseed oil soapstock fatty acids of initial I.V. 103 could be fractionated into liquid fraction (I.V. 132-119, yield 65-75%) and a solid fraction (I.V. 49-55, yield 35-25%).

Levin *et al.*[24] have described the design of an inexpensive soapstock conversion plant with a capacity of 6 tons of product per day for conversion of vegetable oil foots to crude fatty acids.

The most recent work on cottonseed oil soapstock is that of M. F. Stansbury *et al.*[25] who have exhaustively studied the composition of acidulated cottonseed soapstocks as influenced by the commercial methods of processing seeds and oils. About 100 different samples of acid oils from different cottonseed mills were analysed for total (oxidized and unoxidized) fatty matter, unsaponifiable matter, moisture, neutral oil, total phosphorus and gossypol. They have also calculated the fatty acid composition, based on iodine values and thiocyanogen values of the unoxidised total fatty matter, and pH of the aqueous extract of the acidulated soapstock. The various cottonseed mills chosen had different methods of winning oils and refining them, ranging from hydraulic pressing and batch kettle refining to solvent extraction and continuous centrifugal refining or miscella refining. The results have been discussed in regard to the relationship between different combinations of processing techniques, and the nature of the acidulated soapstocks, which included the refining loss, moisture content, unsaponifiable matter, oxidized fatty acids, gossypol, phosphatides, neutral oil and fatty acid composition of the unoxidized fatty acids.

Plan of the Present Work

The above literature survey showed that considerable work had been done in India and abroad on cottonseed oil soapstock. It was therefore, proposed to see how commercial Indian cottonseed oil soapstocks obtained from different factories responded to various upgrading treatment. Specific aspects of study were:

(1) analysis of various samples of soapstocks,

(2) improving the colour of the soapstock by various treatments, and

(3) distillation of crude fatty acids.

Experimental

I. ANALYSIS OF COTTONSEED OIL SOAPSTOCKS

Samples of soapstocks were obtained during laboratory refining of crude cottonseed oil as well as from various cottonseed oil mills. These were analysed according to the A.O.C.S. Official and Tentative Methods. The analytical values are given in Table II.

The percentages of total fatty matter and moisture in Table II do not add upto 100. This is because the analysis does not include combined and free alkali, mineral salts, glycerine, etc.

The analytical data of the soapstocks from 5 cottonseed mills show a large variation in fatty matter and neutral oil contents. Samples from a single mill (Hubli) obtained at different periods, show that the fatty matter content remained fairly constant (28-35%), as did also the neutral oil content (10-13%). It is also observed that when the soapstock is fairly soft (*i.e.* moisture is high), the neutral oil content is less, while if the soapstock is harder (*i.e.* moisture is less) the neutral oil content is higher (cf. samples 2-5 and 6-9). The oxidized fatty acids, which were found to be in appreciable amounts (15-24%) were in the form of a dark or light brownish-grey powder, soluble in ethyl ether.

TABLE II

Analysis of Cottonseed Oil Soapstocks

Sample No.	Sources of the soapstock.	Total fatty matter (unoxidized) %	Oxidized fatty acids %	Neutral oil %	Moisture %
1.	Laboratory sample	60.1	...	29.6	...
2.	Sundatta Cottonseed Utilization, Ltd. Hubli (i)	22.9	17.5	4.4	44.4
3.	do (ii)	35.8	14.2	13.8	45.1
4.	do (iii)	28.9	17.5	10.3	45.3
5.	do (iv)	28.6	16.1	13.8	56.4
6.	New Kamla Oil Mills (Amraoti)	42.7	16.6	15.5	24.5
7.	Mansingka Oil Mills (Khandwa)	46.7	15.5	19.1	21.9
8.	Hanuman Oil Mills (Khamgaon) (Fresh)	39.8	23.7	21.7	28.4
9.	do (Old)	43.4	18.7	27.5	25.3
10.	Indian Cotton Oil Mills (Navsari)	35.4	9.9	14.2	45.4

Note:—Samples 2-5 were soft; samples 6-9 were hard solids.

The *oxidized fatty matter* of some of these soapstocks was analysed for saponification value and iodine number which are given below:

Sample	Saponification value	Iodine number
Hubli (iii)	206.8	110.0
Hubli (iv)	202.0	...
Navsari	200.9	108.1

II. BLEACHING OF THE SOAPSTOCK AND THE ACID OIL

The main bleaching agents used were H_2O_2, NaOCl and $NaClO_2$ (with $SnCl_2$ as activator). These were used in various proportions and under different sets of conditions.

In general, the raw cottonseed oil soapstock or its acid oil is not amenable to any of these bleaching agent when the latter is used in moderate proportions. However, if the soapstock is first repeatedly alkali-grained to give a brownish coloured soap, it can be further decolourised with $NaClO_2$.

The results for $NaClO_2$ are shown in Table III.

TABLE III

$NaClO_2$ Bleaching of Soapstock

Expt. No.	Source of the soapstock	$NaClO_2$ %	$SnCl_2$ %	Colour of the starting material	Colour of the final product
1.	Commercial raw	1.5	2	Black	Black
2.	Grained 3 times	0.4	1	Brown	Light brown
3.	Grained 5 times	1.5	1	Orange	Light yellow
4.	Commercially once-grained	1.0	2	Dark brown	Light brown
5.	Commercially once-grained	2.0	4	Dark brown	Light brown

III. SOLVENT TREATMENT OF SOAPSTOCK

The dried soapstock was treated both in the hot and the cold with many organic solvents (hexane, ethyl ether, chlorobenzene, carbon tetrachloride, chloroform, ethylene dichloride, dioxane) with a view to extract the colouring matter. It was found that there was no colour removal in the cold. When treated in the hot, chlorobenzene, ethylene dichloride and dioxane were somewhat effective.

IV. REPEATED ALKALI-GRAINING OF THE SOAPSTOCK

Most of the impurities present in the soapstock are soluble in caustic lye, which also tends to dissolve some soap. Graining with brine was not found to be effective.

The soapstock was completely saponified and then grained with definite quantities of 40% caustic soda solution. The mixture was kept warm for about 2 hours and then allowed to stand overnight. Lye was removed the next day. The quantity for each graining was 2 to 3 times that required for saponification of the neutral oil present in the soapstock. It was found that to obtain a pale brown soap from black soapstock, something like 5 successive grainings were required. The yield of the soap in small-scale experiments was found to be 60-70% (on total fatty matter basis) while the total amount of alkali consumed was 30-40% of the weight of the soapstock taken.

V. SEPARATION OF SOAPSTOCK FATTY ACIDS BY UREA ADDUCT FORMATION

This was carried out according to the details given by Achaya *et al.*[11] in their patent. Results are given in Table IV.

TABLE IV

Fractionation by Urea Adduct Formation

Expt. No.	Source of the soap stock.	Alcohol-insoluble fraction			Alcohol-soluble fraction		
		Petroleum ether insoluble[a] I.V.	Ethyl ether soluble[b] I.V.	Insoluble colour	Petroleum ether soluble[c] I.V.	Ethyl ether soluble[d] I.V.	Insoluble colour
1.	Hubli (iii)	44.3	1.86	Black powder	92.3	109.2	Black powder
2.	Khamgaon	43.9	1.21	Black powder	119.2	...	Black powder
3.	Navsari (I.V. 108)	44.7	35.1	Black powder	125.6	...	Black powder

Note:—*a.* This fraction was a light brown solid (soft).
b. This fraction was a dark red solid (hard).
c. This fraction was a pale orange liquid.
d. This fraction was a dark red liquid.

It is clear from Table IV that the fatty acids could be fractioned into low and high iodine value fractions by this method. The colour is also improved considerably. The amounts of solvent required for complete removal of fatty acids is rather high.

VI. DISTILLATION OF FATTY ACIDS (LABORATORY-SCALE)

In the laboratory, distillations were carried out in a ground-glass distillation unit under a low pressure of 2-3 mm. of mercury. The jet-black fatty acids from raw (saponified) soapstock gave, on distillation, grey or dark-brown fatty acids, while fatty acids from the grained soapstock gave a very light-coloured product. Besides, the yield in the first case was low (50 to 60%) while in the latter case it was 70-80%. The acid values of the distilled products were between 193 and 200 and saponification values between 202 and 210. The results are shown in Table V.

TABLE V

Distillation[c] of Soapstock Fatty Acids

(1-4mm. of Hg.)

Expt. No.	Source of the soapstock	Vapour temperature, °C	Yield of distilled fatty acids, %	Yield of pitch, %	Colour of the distilled fatty acids
1.[a]	Hubli (raw)	200-220	55.0	31.7	Dirty-grey
2.[b]	Khandwa (raw)	200-222	60.0	34.0	Dark-brown
3.	Amroati (raw)	202-218	37.0	57.0	Brown
4.	Grained	204-219	78.0	21.0	White
5.	Grained	190-206	74.2	22.8	White
6.	Grained	190-210	66.2	31.7	White

Note:—*a.* 45 g of the distilled fatty acids could be separated into 4·6 g. of yellow solid and 40 g. of red liquid portions.
b. 30 g. of the distilled fatty acids could be separated into 19.7 g. of white solid and 9.75 g. of red semi-solid portions.
c. The weights taken for distillation were of the order of 40-90 g. except in Experiment 6, where it was 300 g.

VII. Distillation of Fatty Acids on a Pilot-plant Scale

After the laboratory distillation trials had been found satisfactory, a small stainless-steel fatty acid distillation unit was designed, and fabricated locally. The capacity of the unit was fixed at 10 lb. of distilled fatty acids per hour. The pilot-plant has the following parts: (i) distillation still, (ii) fatty acid pre-heater, (iii) two condensers, one hot and one cold, (iv) pitch receiver, (v) fatty acid receiver, (vi) catchall, (vii) feeding arrangement, (viii) supporting steel structure, (ix) gas burners, and (x) rotary vacuum pump.

A short description of the major parts is given below.

(i) *Distillation still.* This consists of an oil-jacketed chamber provided with a steam distribution device, baffles, a top flange and a connecting goose neck. The still proper is a flat-bottomed cylindrical vessel of 1 ft. internal diameter. It is divided into six compartments by means of vertical plates, which are welded in such a way that the fatty acids entering at one side of the vessel, have to travel in a zig-zag path to reach the outlet at the other end. A distribution device distributes steam uniformly into the six compartments. A pair of baffles is also provided in the path of vapours. The goose neck is of 4-inch diameter and tapers at the condenser-end to a 3-inch diameter. A thermometer records the vapour temperature. The vessel is jacketed to a height of 8-inches from the bottom and the annular space is 2-inches. The jacket is filled with heating oil.

(ii) *Fatty acid pre-heater.* A 1-inch stainless-steel spiral of 7 turns is immersed in a mild-steel cylindrical vessel which contains the heating oil. The outlet of the spiral is connected to the still through a plug valve, while its inlet is connected to the feeding arrangement through another valve.

(iii) *Condensers.* (a) *Hot condenser.* This is a surface condenser with a mild-steel shell 8-inch in diameter and 24-inch in length. There are 12 condensing tubes (0.5-inch in diameter and 24-inch in length) of stainless steel. Hot water is circulated in the shell by means of a pump.

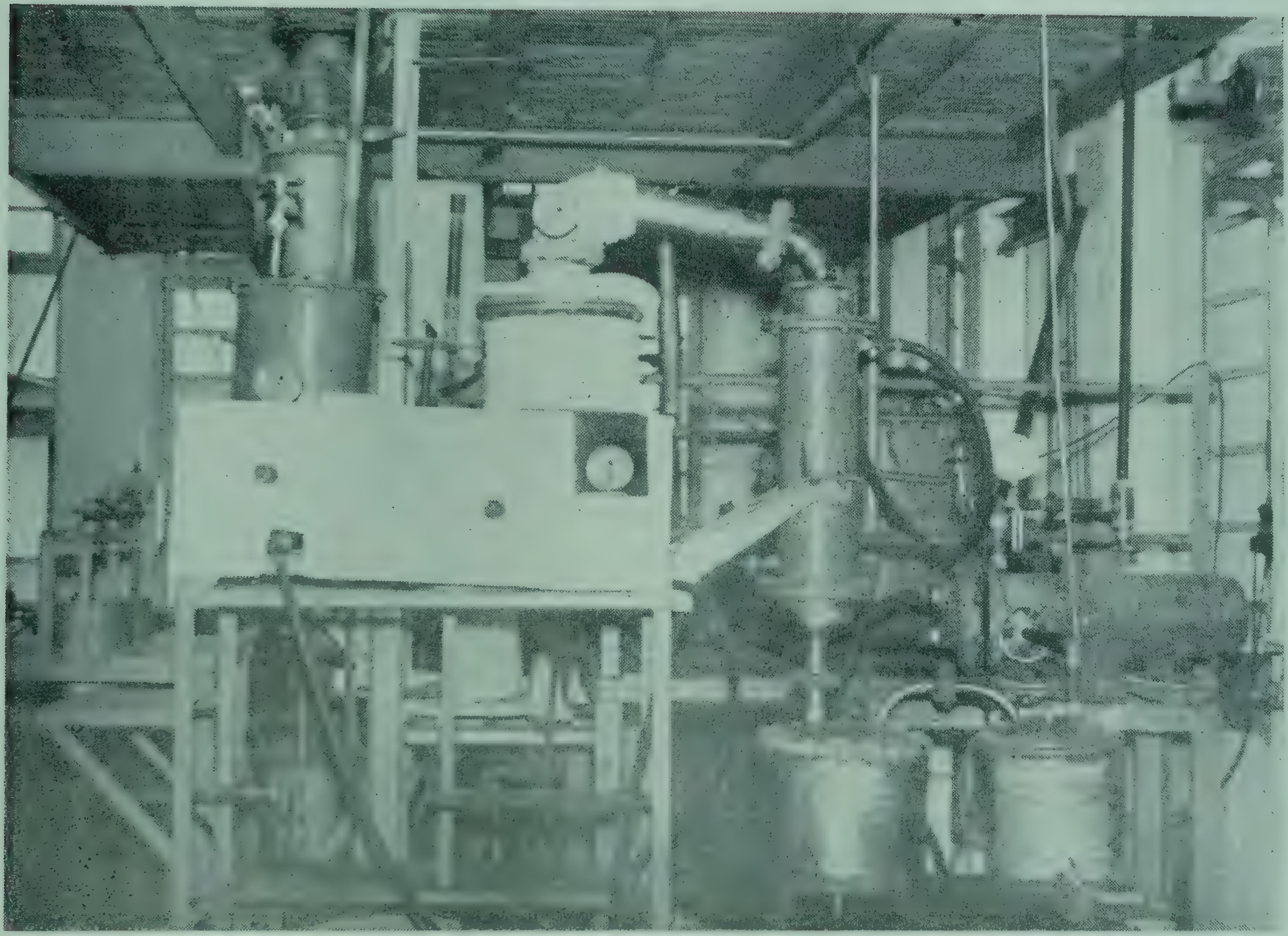
(b) *Cold condenser.* This is also a surface condenser, made of mild steel, condensing almost all of the steam and residual fatty acid vapours.

(iv) *Pitch receiver.* This is a flanged cylindrical vessel of 3-gallons capacity. It is connected to the pitch outlet tube of the still by means of a flange.

(v) *Fatty acid receiver.* This is also a flanged, cylindrical, dish-bottomed vessel (12 inches in diameter and 12 inches in height), connected to the hot condenser on the one hand and to the catchall on the other. The outlet of this vessel is of 1-inch diameter and has a plug valve.

(vi) *Catchall.* This dish-bottomed cylindrical vessel is of 9-inch diameter and 12-inch height. It is connected to the fatty acid receiver and to the final cold condenser. The trapped fatty acids can be removed by an outlet provided at the side wall near the bottom.

(vii) *Feeding arrangements.* Fatty acids are taken in a stainless-steel cylindrical open vessel (feed tank, 10-inches diameter and 16-inches height) and during operations of the plant, they are continuously sucked into the pre-heater coil through an inverted U-tube.



Fatty Acid Distillation Unit

The unit was first tested by batch-distilling in it crude glycerine, coconut oil fatty acids and palm oil fatty acids, all kindly supplied by Godrej Soaps (Private) Ltd. Representative results of these distillations are given in Table VI (a), (b) and (c). Distillation results of cottonseed oil soapstock fatty acids are given in Table VII, and analytical characteristics of the products in Table VIII.

TABLE VI

(a) Steam Distillation of Crude Glycerine at 28.5-inch Hg. Vacuum

Distillation period, hours	Weight of crude glycerine, lb.	Maximum temperature		Weight of products in		Weight of foots	Yield of 96% glycerine
		Jacket °C	Still head °C	Receiver lb.	Catchall lb.	lb.	
1	10.5 (87% glycerine)	230	150	9 (96% glycerine)	3 (18% glycerine)	0.15	92.5

(b) Steam Distillation of Coconut Oil Fatty Acids

(S.V. 258, A.V. 258, colour 6Y+2R)

Distillation period, hours	Fatty acids taken lb.	Maximum temperature			Fatty acids in		Pitch	Yield of distillate
		Jacket °C	Still head °C		Receiver	Catchall		
1	10	205	126	Wt., lb.	7.5	0.5	1.5	80%
				Colour	2.0Y 0.5R	Brown	Dark-brown viscous	
				A.V.	290.9	293.5	70.4	

Note:—1. Colour determination on Lovibond Tintometer 0.25-inch cell, red and yellow units.
2. Average acid value of condensed water was found to be 0.6.
3. Water in the catchall and cold condenser was hexane extracted. Catchall water extract A.V. 328.3; condenser water extract A.V. 389.5.

(c) Steam Distillation of Palm Oil Fatty Acids at 28.8-inch Hg. Vacuum

(S.V. 206.1, A.V. 196.6, colour yellowish)

Distillation period, hours	Fatty acids taken lb.	Maximum temperature			Fatty acids in		Pitch	Yield of distillate
		Jacket °C	Still head °C		Receiver	Catchall		
1.2	14	250	177	Wt., lb.	11.5	2.0	0.5	96%
				Colour	White	Greenish	Black	
				A.V.	211.3	214.9	20.0	
				S.V.	...	...	195.5	

TABLE VII

Cottonseed Oil Soapstock Fatty Acid Distillation at 28.29-inch Hg. Vacuum

Expt. No.	Source of the fatty acids	Raw fatty acids		Maximum temperature		Distilled fatty acids			
		Colour	Wt. lb.	Jacket °C	Still head °C	Wt., lb.	Yield %	Colour	Wt. of pitch. lb.
1.	Laboratory grained soapstock	Dark brown	6	240	150	4.2	70	Brown	0.5
2.	Commercially grained	Brown	12	235	149	10.0	83	Light brown	2.0
3.	Commercially grained	Brown	12	230	145	10.5	87	Light brown	1.0
4.	Distillate of 3	Light brown	10.5	230	155	7.75	73	Pale brown	2.5

Note:—The pitch was a jet-black viscous liquid, except in experiment 4, where it was a dark-brown viscous liquid.

TABLE VIII

Analytical Results of Cottonseed Oil Soapstock Fatty Acid Distillation

(*a*) *Distillation data*

Expt. No.	Original fatty acids			Distilled fatty acids			Pitch	
	Acid value	Sap. value	Iodine value	Acid value	Sap. value	Iodine value	Acid value	Iodine value
1.	195.7	206.9	101.4	203.4	206.5	100.9	...	...
2.	196.2	202.1	108.1	204.6	210.0	93.7	...	...
3.	196.2	202.1	108.1	208.1	209.7	102.3	71.5	97.2
4.	208.1	209.7	102.3	212.5	...	91.8	175	114.5

Note:—The pitch was found to be completely soluble in ethyl ether and partially soluble in 95 % ethanol.

(b) *Further processing of distilled acids*

The distilled fatty acids from experiment No. 1, which were in the form of a soft brown mass, were chilled at 5°C. A part was pressed at that temperature in a hydraulic press. Very little liquid came out at 5°C but by slowly allowing the temperature to rise to 25°C and increasing the pressure very gradually to 2200 p.s.i., a considerable portion of liquid fatty acids could be removed.

162 g. of mixed fatty acids on pressing at 25°C gave 118 g. of solid white fatty acids and 35 g. of reddish brown liquid acids.

	Acid value	Iodine value
Mixed fatty acids	203.4	100.9
Solid fatty acids	206.2	68.3
Liquid fatty acids	195.3	131.4

Conclusions

It thus appears that only two methods of disposing of the soapstock are effective: one is the alkali-graining and the other is the distillation of fatty acids. The alkali method would be expensive on account of the considerable quantities of alkali required. Therefore, be only practical method is distillation.

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6. SUPPLEMENTARY VALUE OF LOW-FAT COTTONSEED FLOUR TO POOR VEGETARIAN DIETS BASED ON CERTAIN CEREALS

By

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1. The supplementary value of alcohol-extracted cottonseed flour to poor vegetarian diets based on wheat, ragi, rice and jowar was determined by the rat growth method. The results showed that when incorporated at 10% level in the diet, cottonseed flour has a marked supplementary value to diets based on ragi and jowar and only a moderate supplementary value to rice and wheat diets.

2. The protein efficiency ratio of the proteins of alcohol-extracted cottonseed flour (at 10% level) was found to be slightly superior to those of expeller-pressed meal.

3. The supplementary relation between the proteins of cottonseed flour, jowar and wheat was determined by the rat growth method. The results showed that the proteins of cottonseed flour supplemented to a marked extent the proteins of wheat and jowar.

Introduction

Considerable interest has recently been evinced in many countries in the utilisation of specially-processed low-fat oilseed flours as sources of protein for supplementing human diets.[1-8] Processed soya flour suitable for human consumption is being manufactured in large quantities in the U.S.A. Good-quality peanut and cottonseed flours are being produced in limited amounts.[2] Recently specially-processed low-fat peanut flour has been used successfully in the production of Indian multipurpose food and in fortifying macaroni product.[7,8] Cottonseed meal is available in large quantities in India as a by-product of the cottonseed oil industry. The meal contains about 40-45 per cent of proteins of fairly high biological value.[5] Kuppuswamy *et al.*[5] studied the supplementary value to the poor rice diet of expeller-pressed cottonseed meal. No information is however available on the supplementary value of cottonseed flour to diets based on other cereals and millets, and also on the supplementary relationship of cottonseed proteins to those of certain cereals. In view of this, investigations were undertaken to find out (1) the supplementary value of alcohol-extracted cottonseed flour to poor vegetarian diets based on rice, jowar, ragi and wheat, (2) the biological value of the proteins of expeller-pressed and alcohol-extracted cottonseed meal, and (3) the supplementary relations between cottonseed proteins and certain cereal proteins.

Experimental and Results

Chemical Composition of Low-fat Cottonseed Flour

Kernels prepared from good-quality cottonseed were used in this study. The preparation of the meal from the kernels was carried out by two methods: (1) pressing the kernels in an expeller (Rose-Down) under standard commercial conditions, and (2) extracting the flaked kernels thrice with boiling absolute alcohol for a total period of 1.5 hours in a pilot extractor. The extracted material was freed from alcohol by indirect steam-heating under vacuum. Both the expeller-pressed and alcohol-extracted flours were powdered to pass through 50 mesh sieve. The proximate principles and minerals in the flours were determined according to A.O.A.C. Methods.[9] Thiamine was determined according to the method of Swaminathan.[10] Gossypol was estimated according to the method of Pons and Guthrie.[11] The results are given in Table I.

TABLE I

Composition of Expeller-pressed and Alcohol-extracted Cottonseed Flour

Constituent	Expeller-pressed cottonseed flour %	Alcohol-extracted cottonseed flour %
Moisture	7.9	11.3
Mineral matter	5.65	7.21
Crude fibre	1.70	2.0
Protein (Nx6.25)	39.4	45.9
Fat (ether-extractives)	15.1	1.9
Calcium (mg.)	323.5	390.0
Phosphorus (mg.)	640.0	757.0
Gossypol (mg.)	141.5	72.3
Thiamine (mg.)	0.62	0.35

The Supplementary Value of Cottonseed Flour to Poor Vegetarian diets

The supplementary value of the alcohol-extracted cottonseed flour to poor vegetarian diets based on wheat, ragi, rice and jowar was determined by the rat-growth method. The composition of the diets used in this investigation was the same as that described by Subrahmanyan *et al.*[12] The diets were supplemented with alcohol-extracted cottonseed flour by replacing 10% of the cereal in the diet by an equal quantity of the cottonseed flour. Weanling albino rats (weighing between 40-50 g.) were divided into different groups in a randomized block design. They were fed *ad lib* for a period of 8 weeks on the different diets. The animals were weighed weekly and records of food intake were maintained. The results are presented in Table II.

The Biological Value of Proteins of Cottonseed Meal

This study was undertaken to find out whether there is any difference in the biological value of proteins of expeller-pressed and alcohol-extracted cottonseed flours. The rat-growth method of Osborne, Mendel and Ferry,[13] as described by Swaminathan,[14] was used in these studies.

TABLE II

Supplementary Value of Cottonseed Flour to Poor Vegetarian Diets Based on Ragi, Wheat, Rice and Jowar

(Duration of the experiment: 8 weeks)

Group No.*	Diet	Average daily food intake (dry wt. basis) g.	Average weekly gain in weight g.	
1.	Poor ragi diet	8.8	7.73	± 0.52 (15 d. f.)
2.	Poor ragi diet+10% cottonseed flour	9.9	13.69	
3.	Poor wheat diet	6.5	6.90	
4.	Poor wheat diet+10% cottonseed flour	6.1	8.96	
5.	Poor rice diet	7.4	6.20	± 0.256 (7 d. f.)
6.	Poor rice diet+10% cottonseed flour	7.5	7.91	
7.	Poor jowar diet	9.3	9.47	± 0.335 (11 d. f.)
8.	Poor jowar diet+10% cottonseed flour	9.4	11.53	

* Group 1–4 contained 3 males and 3 females.

Group 5&6 contained 3 males and 5 females.

Group 7&8 contained 7 males and 5 females.

Two groups of weanling albino rats weighing between 40-50 g. and equally distributed according to sex and litter mates were fed on synthetic diets in which alcohol-extracted or expeller-pressed cottonseed flour formed the sole source of protein. The level of protein in the diet was maintained at 10%. The diets were adequate with respect to other dietary essentials, namely fat, minerals and vitamins. Careful records of daily food intake and weekly gain in weight were maintained. The protein efficiency ratios were calculated for periods of 4 and 8 weeks. The results are presented in Table III.

TABLE III

Protein Efficiency Ratio of the Proteins of Expeller-pressed and Alcohol-extracted Cottonseed Flours (at 10% Protein Level)

Group No.*	Diet	Protein efficiency ratio			
		4 weeks		8 weeks	
1.	Expeller-pressed cottonseed flour	1.75	±0.11 (7 d. f.)	1.61	± 0.057 (7 d. f.)
2.	Alcohol-exracted cottonseed flour	1.95		1.80	

* Each group contained 8 male rats.

Supplementary Relations between the Proteins of Cottonseed Meal and Cereal Proteins

The supplementary relations of cottonseed proteins to those of wheat and jowar were determined by the rat-growth method of Osborne, Mendel and Ferry.[13] Alcohol-extracted cottonseed flour was used in this study. Five groups of weanling albino rats (10 animals in each group distributed equally according to sex and litter mates) were fed on synthetic diets containing (a) cottonseed flour, (b) cottonseed flour+wheat, (c) wheat, (d) cottonseed flour+jowar, and (e) jowar, as the only sources of protein in the diet. The level of proteins in all the diets was maintained at 10%. In the case of diets containing proteins from two sources (diets 2 and 4) each foodstuff contributed 5% protein. All the diets were adequate with respect to fat, minerals and vitamins. Careful records of daily food intake and weekly gain in weight were maintained. The protein ratios were calculated for periods of 4 and 8 weeks. The results are given in Table IV.

TABLE IV

Supplementary Relations Between the Proteins of Cottonseed and Those of Wheat and Jowar (at 10% Protein Level)

Group No.*	Diet	Protein efficiency ratio			
		4 weeks		8 weeks	
1.	Cottonseed flour	1.86	± 0.08 (32 d. f.)	1.37	± 0.07 (32 d. f.)
2.	Cottonseed flour + wheat	1.93		1.69	
3.	Wheat	1.40		1.26	
4.	Cottonseed flour + jowar	1.49		1.32	
5.	Jowar	0.85		0.63	

* Each group contained 5 males and 5 females.

Discussion

It may be seen from Table I that alcohol-extracted cottonseed flour contained less gossypol than expeller-pressed flour. This is because alcohol removes a greater part of the gossypol present in the material.

The results given in Table II showed that the average gain in weight of rats fed on diets supplemented with cottonseed flour at 10% level is greater than that of the control group in each case. It is of interest to note that cottonseed flour has a marked supplementary value to diets based on ragi and jowar and only a moderate supplementary value to rice and wheat diets.

It will be observed from Table III that the protein efficiency ratio of the proteins of alcohol-extracted cottonseed flour is slightly greater than that of expeller-pressed meal, the difference being significant at 5% level. The results presented in Table IV show that the proteins of cottonseed flour supplement markedly those of wheat and jowar proteins. This may be due to the fact that cottonseed proteins are rich in lysine, in which the proteins of wheat and jowar are deficient.[15] Jones and Divine[4] and Womack *et al.*[16] also observed that the proteins of cottonseed meal supplemented those of wheat.

The protein efficiency ratio of the proteins of jowar was found to be less than that of wheat. The low protein efficiency ratio of jowar proteins may be due to its deficiency in some of the essential amino acids as compared with wheat. The results obtained in the present study have clearly shown that cottonseed meal can be used as a supplement to diets based on wheat, rice, jowar and ragi.

Acknowledgment

Our thanks are due to Shri A. N. Sankaran and Miss K. Indiramma for the statistical analysis of the results.

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7. A PROVENDER INDUSTRY BASED ON COTTONSEED CAKE AND HULLS

By

T. S. RAMASWAMY

(Tata Oil Mills Co. Ltd., Sewri, Bombay-15)

The nature of balanced rations for livestock feeding, and the sources of the components, are discussed. The utility of cottonseed cake and hulls is emphasised.

Provender Formulations

Provender milling or the preparation of feeding stuffs for livestock has become an important industry in recent years. Nutrition research has brought to light the importance of balanced food containing the required amounts of carbohydrates, proteins, fat, vitamins and minerals, and the provender miller not only makes straight meals but also balanced rations for various categories of livestock. The formulations vary according to the type and age of animal and various other factors. Balanced rations are now available for the following livestock and poultry.[1]

Cattle	Poultry	Pigs
Dairy cows	Chicks	Breeding pigs
Young beasts	Layers	Bacon pigs
Fatteners	Growers	Young pigs (2-12 weeks)
	Breeders	Suckling pigs
	Fatteners	

In a balanced ration, the carbohydrate requirements are met by using coarse grains like corn, barley and oats. Sweet potato and tapioca are also recommended as sources of carbohydrates. The protein requirements are met by including oilcakes in the mixture. The small amounts of fat in the feeding stuffs have been found to be enough to satisfy the minimum requirements of fat. Whole oilseeds like cottonseed have been found to be too valuable to be given to cattle directly and so only oilcakes are used in balanced rations. The vitamin requirements are met by including cod liver oil in the mixture. Chalk, bone flour and deflourinated phosphate rock powder are included to fill mineral requirements. The formulations necessarily depend upon the local availability of the various materials. The various ingredients are first made into a meal and this meal is then mixed with a small quantity of molasses and converted to pellets or cubes.

The provender industry has some similarities with the mixed fertilizer industry. Though it is possible for the farmer to obtain his requirements of the various fertilizer ingredients separately in the market, he has shown a definite preference for mixed fertilizers, which are therefore immensely popular in foreign countries and in our own country in fertilizer-minded areas like the Nilgiris. If a properly-balanced cattlefeed is supplied to cattle owners everywhere, it is bound to meet with an enthusiastic reception because of its many advantages.

The development of a provender industry will also go a long way in solving the problem of the disposal of cottonseed cake and hulls, with which we are all deeply concerned. The custom in India of feeding whole cottonseed to cattle instead of cottonseed cake and hulls is in sharp contrast to the practice followed in all the other cotton-growing countries. The millions of cattle owners in India could be educated by propaganda and their prejudice against cottonseed cake and hulls overcome, but this is a difficult task. As an alternative, mixed cattlefeed containing these products could be supplied to them, to the benefit of both the cattle owner and the provender miller.

Sources of Components

National organisations in various countries have taken up the task of evolving formulations for balanced cattlefeed. These formulations naturally take into account the availability of the various raw materials in the respective countries. In a country like ours, faced with what seems to be a perpetual deficit of foodgrains, the problem is still more difficult. We have oilcakes to supply the protein requirements. But additional carbohydrates, vitamin A and minerals have to be supplied to cattle in addition to oilcakes. Barley and oats are grown as cattle food and used in the northern parts of India. But for cattle in the south, where milk production is notoriously low, other sources of carbohydrates have to be investigated. The pioneer work of the Central Food Technological Research Institute, Mysore in the direction of utilization of root crops like tapioca is well-known. Root crops yield three times more carbohydrates per acre than cereals. So the provender industry in India has to turn its attention to root crops also for supplementing oilcakes. The use of cod-liver oil or fish oil for supplying vitamins is not advisable in the early stages because of the prejudice of the people against these products. Instead the coloured *Sunhari* variety of sweet potatoes rich in carotene could be cultivated and used as cattlefeed.

Cottonseed Products in Cattlefeeds

Cottonseed cake and cottonseed hulls could advantageously be used in mixed cattlefeed. The nutritive value of cottonseed cake and cottonseed hulls is well-known. The cake contains about 36% of proteins and is rich in phosphates and the 'B' group vitamins. Cottonseed hulls supply roughage in addition to nutrients. One ton of cottonseed hulls has been found to equal the feeding value of 1.4 tons of silage, 330 lb. of corn or 82 lb. of cottonseed cake.[2] Mixed cattlefeed formulations containing cottonseed cake and hulls are given in various publications.[3] These formulations, evolved after a great deal of experimental work, can be used as a basis to evolve formulations to suit our local conditions. As indicated earlier the development of a successful cottonseed crushing industry is intimately connected with finding outlets for the cake and hulls produced. The establishment of a successful provender industry based on these materials will go a long way in solving this problem.

Acknowledgment

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DISCUSSIONS

Discussion Leader: Shri G. V. Sirur,
Sundatta Foods and Fibres,
Hubli.

GENERAL

G. V. Sirur. It is desirable to distinguish between true by-products, like linters, hulls and soapstock, and derived products like vanaspati, chemical cotton, etc. Cottonseed oil and cake have to compete with groundnut products, and this can only be possible if maximum efficiency of removal and recovery of by-products is obtained. The value of hulls, linters and soapstock together form about 15% of the total outturn; hence if one expects a 10-15% return on investment, full value for these products is essential. Oil constitutes some 45% of the value, and cake 40%.

To start with linters, the following outlets are easily possible by 1961.

	Tons
Cellulose acetate	
For rayon	2,000
As flakes	400
As triacetate (mostly for photographic films)	600
Nitrocellulose group	
Explosives (industrial & defence)	400
Lacquers	250
Industrial chemicals like CMC	600
Fillers	
For plastic moulding industry	250
For tyre cord	2,000
Viscose	
Estimated replacement use	32,000
Staple fibre	24,000
Cellophane viscose film	2,000

Today disposal of linters is extremely difficult, because the cottonseed crushers are not producing material of proper quality. Second-cut linters, which are short in length, are needed for acetate rayon, while most producers obtain only the mill-run quality. Indian linters are rich in extraneous iron since proper seed- and lint-cleaning equipment is not used. Silica is also high, and this may perhaps be an intrinsic part of the cell wall, though further study of this aspect is indicated. A rough comparison of Pakistan linters, now imported for rayon manufacture, and Indian first-cut linters would stand thus:

Per cent	Pakistan linters	Indian linters
Moisture	6	6-8
Ash	1	2.5-1.25
Silica	0.1	0.2-0.1
Oxycellulose	8-9	15-9
α-cellulose	97-98	97-92
Iron, p.p.m.	90-100	425-50

In processing linters, good-quality water and pipelines of stainless steel are needed to avoid iron contamination. Ash, silica, iron and proper fibre length (*i.e.* production of second-cut linters) are the main problems.

Hulls are the second important by-product, for which there is a tremendous demand for compound milling and as a cattlefeed; the price is now about Rs. 120/- per ton, whereas a few years ago it was difficult to obtain even Rs. 30/-. It remains to be seen by research whether it would be cheaper to obtain chemicals like furfural from groundnut hulls or from cottonseed hulls.

Soapstock, the third major by-product, sells at about Rs. 60-70 per ton on a basis of 30-40% total fatty matter, but is difficult to dispose of. Work on distillation or urea adduction for recovery of fatty acids, with proper economic data, is very desirable. The method should be fairly foolproof and give an uninterrupted production of fatty acids of good quality.

2. *B. P. Godrej.* The price of Rs. 60-70 per ton quoted for soapstock appears to be on the low side.

3. *Several crushers.* We can offer stocks at this price.

4. *B. Srinivasan.* Is iron in linters bound or free? If free it could be chelated and removed. Is there any work in India on preparation of C.M.C. which is also required in the pharmaceutical industry?

5. *K. S. Srinivas.* Oxalic acid treatment will indeed reduce the iron to as low as 20 p.p.m., and to 5-10 p.p.m. if the process water were to be treated with ion-exchange resins. Iron has an effect on discharge printing, mordanting the dyes used and giving bad discharge effects.

6. *G. V. Sirur.* Two firms have been given a licence to manufacture C.M.C.

7. *R. K. Bhatnagar.* The Shri Ram Institute for Industrial Research, Delhi has developed a process for the manufacture of C.M.C. which has been leased for commercial exploitation to a Bombay firm.

8. *K. S. Murti.* Dr. Srinivas is requested to throw more light on the actual defects in and reasons for unsuitability of cotton linters from both American and *desi* Indian cottonseeds, in respect of first-cut, second-cut and mill-run qualities. What is the demand now for first-cut and mill-run linters?

9. *J. M. Shah.* If Punjab and Pakistan cottonseeds are of the same variety, why do Indian seeds yield linters high in iron? Will any lint-cleaning device reduce the iron?

10. *G. V. Sirur.* The price of soapstock of 35-40% fatty acids, it may be repeated, is Rs. 60-70 per ton, and fatty acid distillation is essential for better economic return. Cottonseed millers must invest more and provide for first and second cutting of linters, since the second-cut variety is the only answer for chemical purposes. Hardly 5-10% of linters are now used, while 60-70% could be used. Pakistan linters are genetically the same as Indian, but proper methods of cleaning and recovery are used there. There is an enormous future for utilisation of linters since woodpulp is now selling at Rs. 1100-1200 per ton. In Japan, both mill-run and first-cut qualities of lint are actually being spun into low count yarn. First-cut linters, of staple length about 0.75 inch, are used for surgical cotton for hospital purposes. ISI Specifications should be relaxed.

11. *B. S. K. Shastry.* A little more attention should be given to the problem of soapstock disposal; while distillation is one way out, an immediate solution needs to be found.

12. *J. P. Varma.* Low-temperature crystallisation of soapstock itself containing 1 mg. tocopherol/100 gm. soap, just as is used for fatty acids, may be considered, with tocopherol as a by-product. The fatty acids can be fractionated to palmitic acid (converted into cetyl alcohol for use in reducing water evaporation in arid areas) and oleic-linoleic acids (for use in the paint industry).

13. *T. V. Subba Rao.* Low-temperature crystallisation is only applied to fatty acids, and not to soapstock as such.

14. *C. R. Das.* In the U.S.A., some part of soapstock is mixed with the cake for use as cattlefeed. Fatty acid distillation need not be a complicated operation; in a plant seen working in New Orleans, the soapstock is saponified, acidified and distilled in a simple retort under vacuum to give fatty acids of reasonably light colour.

15. *K. S. Murti.* The plant referred to is at the Southern Cotton Oil Co. The residue amounted to 10-20%, against 10-7% in an efficient plant. The vacuum had to be at least about 30 inches for reasonable distillation temperatures.

16. *K. S. Chari.* A plant from Lurgi Gesselschaft is being installed at the Regional Research Laboratory with a capacity of 100 kg. per batch. After working it for a while, the laboratory will be able to provide designs for simpler distillation units for the Indian industry.

17. *B. P. Godrej.* At our factory, the fatty acids are bleached with active earth and active carbon, when about half as much colour is removed as by distillation.

18. *N. G. Chatterji.* A simple distillation unit could easily be devised; a mild steel vessel should suffice, with stainless steel only along the actual vapour path, and vacuum provision.

19. *K. S. Chari.* Design ought to be a simple matter, but fabrication in India, even by reputed firms, is not at all as satisfactory as it should be, and we have recently had difficulty even in fabricating a rotary digester which can withstand a pressure of 80 lb.

20. *B. P. Godrej.* Even mild steel for the retort would not do, since iron soaps would be formed which, apart from darkening the distillate considerably, would reduce yield drastically.

21. *R. K. Bhatnagar.* The Shri Ram Institute would be glad to help in the fabrication of any units of the types described.

22. *B. Srinivasan.* A Calcutta firm has supplied excellent equipment for manufacture of fine chemicals.

23. *G. V. Sirur.* The difficulty is one of design, and Dr. Chatterji's and Dr. Chari's offers to supply these are most welcome. Fabrication could be done without much difficulty by any reasonably good plant workshop.

J. G. Kane (communicated). Can we not agree to reserve the word "foots" to denote the impurities that settle down on storage of unrefined oil or that separate in degumming the oil, and not use it as an alternative soapstock?

PAPERS 1 & 2

1. *G. V. Sirur.* The first paper is a review and the author of the second paper is not present, so the next can be considered.

PAPER 3

1. *K. S. Srinivas.* Sirsilk Ltd. is the only industry in the country using cotton linters, the quantity being about 2000 tons per year, of second-cut grade only. When the plant was originally put up by the Government of Hyderabad, no foreign concern was prepared to give the necessary technical know-how except a Lancashire firm (LANSIL) which gave us its entire, rather outmoded plant, designed for American linters. Only some five factories using linters for cellulose triacetate films exist in the world, and these are unwilling to part with their know-how; Japan had managed to work out its own. So much is spent on research in advanced countries, and it would be difficult to compete.

Regarding Indian linters, the general quality is not of the standard required. Sirsilk can now put in 66% of Indian linters into their production schedule, but classified in three grades (about $\frac{1}{3}$ each) according to the final fabric quality desired. All the linters produced are not of the quality required to give the best fabric acceptable in the international market.

About 600 tons of second-cut Indian linters are now available; if of reasonably good quality, Sirsilk could absorb half the potential Indian production. The main difficulty of utilisation is the amount of time necessary for de-ironing the Indian product; no one has also studied the acetylation, or the filtering characteristic in acetone. The grading of Indian linters is also overdue, and there are some good suggestions in a later paper from the Regional Research Laboratory. Research should be directed to improving linter quality, to pilot-plant work on a scale large enough to be useful, and on using alternate raw materials for cellulose acetate manufacture. And this research must be expedited, and can only be done by Indians.

2. *G. S. Sidhu.* The U.S.A., today the largest processors of cellulose, which is derived about equally from linters and woodpulp, produces as much chemical cotton as it does steel. The production of chemical cotton is always a custom-made job, and buyers visit the consuming industry and discuss their specifications. In India there is only one consumer, and it is not very responsive to overtures. Iron (even when bound) and ash can be removed from linters; α-cellulose is of prime importance, and in the U.S.A. 73% is used as the standard, and a premium obtained for α-cellulose contents above, and a discount for contents below, this figure. Similar standards on which to base the price structure are necessary in India. It must be realised that the analysis of linters is only a guide to its quality, and that actual processing until the bleach stage is necessary for evaluation; the Regional Research Laboratory is prepared to do such work, and even to further acetylate or nitrate the product. The main problems are avoiding dust and hull contamination of linters, and probably a great deal can be done by assuring the quality and type of seed, and hence of the linters. The nitration outlet is likely to rise above the present figure of 2000 tons.

3. *S. Zainul Abideen.* Hull pepper raises the iron content. A central linter purification unit could be considered. At present Indian linters are probably cheaper than soft waste and bamboo pulp, though costing is necessary and study is worthwhile. There may be foreign exchange difficulties in the way of obtaining machinery for producing second-cut linters.

4. *K. S. Chari.* Dust can be reduced by introducing proper seed-cleaning equipment. Trying to cut more linters introduces more hull pepper, which can also be reduced by proper adjustment of the units.

5. *G. V. Sirur.* Every crusher should put in a lint-cleaning unit and not be satisfied with the equipment used at the consuming end. It is desirable to have a liaison office at the Regional Research Laboratory, Hyderabad to advise the industry in regard to linters.

PAPERS 4 & 5

1. *K. T. Achaya.* It will be noticed that the recoveries of fatty acids are 82-88%, similar to those in distillation. Though the work was done in 1953, the economics on a pilot-plant scale are not yet worked out, but this is soon scheduled to be done.

2. *N. Bhojraj Naidu.* The urea adduct method of recovering fatty acids from soapstock also leads to a fractionation according to unsaturation, and is to be commended. Russian workers have indeed used the mixed fatty acids from soapstock for alkyd manufacture by increasing the functionality of the alcohol.

An instrument for giving accurate and repeatable colour readings, which uses a cathode ray tube, is the Gardiner Direct Reading Colouroscope, recently described in the July 1958 issue of the American Paint Journal.

3. *G. V. Sirur.* The urea method seems very interesting, and the economic data should be obtained soon.

PAPER 6

1. *M. Narayana Rao.* In the presence of celluloses and hemicelluloses, protein becomes less available to cattle, hence the importance of delinting. Perhaps the fibre present prevents the enzymes from attacking the protein. Moreover delinted cake contains twice the protein of undelinted cake, and military farms in this country insist on the former.

2. *B. S. Lulla.* An economic method of using oilcake is to convert the proteins by microbiological methods to a predigested form. Foreign products of this type are Marmite (30-35% predigested protein) and "Ledinac" (50-55%). At the Central Food Technological Research Institute, Mysore, similar foods have been made, and though especially standardised for soya bean meals, can be extended to other oilcake meals also, and can similarly be used to convert other low-grade foods into a high-quality for human consumption.

3. *T. V. Subba Rao.* If linters, which are cellulosic, do hinder enzyme action, what about the many other cellulosic materials which animals eat? I feel that this aspect should not be emphasised, though of course delinting is advocated.

4. *G. V. Sirur.* There seems to be no definite evidence for the phenomenon described.

5. *M. Narayana Rao.* So many Indian diets are poor in protein, and low-fat cottonseed flour is an admirable supplement, being rich in lysine. Using alcohol for solvent extraction, the gossypol content of the flour can be reduced to as low as 0.02%. Though used only for feeding swine in the U.S.A., it can form in India an effective diet for human beings.

PAPER 7

1. *G. V. Sirur.* Provender industry is the only rational and ultimate method of providing fodder for the cattle. There appears to be only one provender mill in India on a small scale at Gooty.

SECTION VII

FUNDAMENTAL STUDIES

Discussion Leader: Dr. K. S. Murti,
Oil Technological Institute,
Anantapur.

1. SOME OBSERVATIONS ON THE COMPOSITION AND CHARACTERISTICS OF INDIAN COTTONSEED

By

K. S. MURTI

(Oil Technological Institute, Anantapur)

1. Estimates of cottonseed production deduced from an average ginning percentage of 33⅓% are likely to be erroneous, and individual ginning percentages for each variety should be used; total cottonseed production for 3 years on this basis is given, as also the production of desi *(70%) and American-type seed (30%).*

2. The average oil content (10% moisture basis) of American-type seed is 18.3; 97.6% of them contain 15% or more oil. For desi *seed, average 17.8%, 92.4% of the samples contained 15% or more oil. Hence both could well be crushed.*

3. Linter percentages (10% moisture basis) of American and desi *seed respectively are 10.3 and 5.8. About 55% of* desi *seed however contain more than 5% lint, and 23% more than 7.5%, hence such* desi *seed should also be delinted during processing.*

4. The average protein content of both types of Indian seed is about 18.6% (10% moisture basis), lower than the 20.8% for cottonseed in the U.S.A. Hence the corresponding cakes will contain less protein.

5. Gossypol contents of whole seed (0.43—0.88%) and of uncooked kernels (0.90-1.68%) are similar for both Indian seed types and also for the corresponding U.S.A. products.

6. The ratio of the seed index for seed from the U.S.A., American-type found in India and desi *seed is 2:1.5:1.*

7. The average hull-kernel ratio is 0.88 for desi *seed and 0.74 for American-type seed; if linters are included with hulls, the ratios become 0.97 and 0.95 respectively.*

8. Data on various physical and chemical characteristics of Indian cottonseed oils are given. Gossypol contents of Indian oils averaged 0.37%.

9. Phosphatide contents of whole seed (0.639—0.794%), hulls (0.125—0.110%), oils (0.46—2.74%) and cake (0.77—1.54%) indicate that degumming is necessary during processing.

10. Technological aspects are indicated.

Introduction

In an earlier paper presented by me at the Symposium on "Indian Oils and Fats and their Utilisation" held seven years ago in November, 1951, under the auspices of the National Chemical Laboratory, Poona, entitled "The Future of Cottonseed Oil Milling and its Utilisation in India",[1] a critical and detailed survey of the industry in India was made. Therein, the economic significance of the industry to India, the factors contributing to the then backward condition of the industry in the country and the steps necessary to be taken to establish the industry on proper lines were stated. I am gratified to note that some notice of that article was taken in the country. I then pleaded that in order to stimulate the starting of the cottonseed milling industry systematically and in order that it should thrive, complete technical data on the characteristics of Indian cottonseeds and their products is required. To quote,[1] "It is essential to study the composition of several varities of Indian cottonseed, their variation with seasons and locality, with regard to proteins, oil, colouring matter, the toxic material, gossypol, the lint content and its nature, the amount and composition of the hulls in the seed, on a very extensive scale." In that Symposium paper, I had also pleaded that as the subject is vast and the interests at stake so high, it is quite essential that several research organisations should take up this work simultaneously on a co-operative basis and enumerated the various problems that needed immediate attention. I am glad to state that since then some significant progress has been made both in the industry and research in the field. I am also happy to state that this symposium being held exclusively on this specific subject of cottonseed and its by-products justifies the emphasis I then placed on the importance of the subject and that this gathering of scientists, technologists and representatives of the industry, trade and governmental organisations is symbolic of the co-operative efforts being made in the country since then. I am happy too that this host organisation, the Regional Research Laboratory, and the Oil Technological Institute, Anantapur are playing some worthwhile part in the development of this industry in the country.

Coming to the subject matter of the present paper, a detailed and thorough knowledge of the composition and characteristics of cottonseed, which is the raw material for the cottonseed processing industry, and their variation with different varieties and regions and other environmental factors is an essential pre-requisite for the basis and development of the industry, just as a thorough knowledge of the physical and chemical characteristics and their variations in the raw material for any other industry is essential. The obtaining of such data is complicated in the case of cottonseed, particularly in India, due to the existence of about fifty different trade varieties of *desi* and American-type seed and further due to the introduction of more improved strains of cotton in the country progressively, as a result of excellent developmental research carried on in that field under the aegis of the Indian Council of Agricultural Research and the Indian Central Cotton Committee. In other countries, including the U.S.A., the number of varieties produced appears to be comparatively less. Therefore, with a view to make available to the industry such data on the characteristics and composition of the different commercial varieties in the country, it was planned in 1952 to obtain and analyse systematically a large number of samples of cottonseed each year from the different cotton-producing States of India. With a view to ensure the representative character of the commercial varieties obtained, the help of the Agricultural Departments of the different States has been sought for and liberally obtained. The samples were drawn by the Agriculture departmental officers from the commercial produce according to the standard method of sampling and sent, together with information on the history of each sample such as the variety, local or trade name, locality of growth, harvesting season (picking) and average rainfall. Information regarding the last two items could not, however, be obtained in many cases. To date, a total of 585 samples have been obtained, of which 567 samples have been studied and the data presented in this paper. In this connection, I would like to mention that in the U.S.A., annually more than 150,000 samples were drawn and analysed for their contents of oil, moisture, foreign matter and linters, and the F.F.A. of the oil. Though this data is primarily designed for grading the cottonseed, it has been coupled with other information obtained from the licensed samplers to provide ample data on the seed produced in every part of that country which is highly valuable and utilised by the cottonseed processing industry in the U.SA.

Experimental

In determining the analytical data on the seed, the Official A.O.C.S. Methods have been uniformly adopted, as these methods cover completely all characteristics of cottonseed and its products. It may not be out of place to mention here that the earlier workers in this field in India do not seem to have followed any uniform methods for their analysis but seem to have employed methods convenient to them and/or known at that time. In order to compare the data on the different varieties of the seed obtained by different workers, we have calculated the data obtained on a 10% moisture basis, as the average moisture content of Indian cottonseed is close to 10%.

Discussion

The number of samples drawn for each variety was originally designed to be in proportion to the size of production of that variety. However, in actual practice, this could not be done in all cases, in view of the practical difficulties in the way of getting large number of samples of the more important varieties from all the States, particularly from the more distant States. In this connection, I venture to suggest that the method of estimating the seed production of the different varieties in the country as adopted by the Economics and Statistics Directorate of the Food and Agriculture Ministry, the Indian Central Cotton Committee and the Agriculture Departments of the different States needs some revision. It is estimated at present from the production of lint, in terms of bales of 392 lbs. of each variety of cotton, using a common ginning factor of 33⅓%, though it is quite well-known that the ginning percentage differs for the *desi* and the American-type and from variety to variety in each of these two groups, and also for the same variety from State to State and from year to year even in the same State. Therefore, a more correct basis for estimating the cottonseed production of different varieties, in my opinion, would be to use the average ginning per cent of a particular variety in that year, in the particular State, and to calculate the seed from the lint of each variety produced, in each State, and then total up. In fact, we have estimated the production of cottonseed in India on an earlier occasion[2] on this basis. Estimates of total production of cottonseed in India, prepared on the two bases mentioned above during the years 1953-54, 1954-55, and 1955-56 are given for comparison in Table I.

In fact in the U.S.A., till 1944, cottonseed production was estimated by using a constant seed: lint ratio of 65:35. But from 1944 onwards, the Census Bureau modified this ratio to conform approximately to actually realised yields.[3]

The distribution of the samples of *desi* and American-type seed obtained from the various States and analysed is given in Table II.

TABLE I

Estimates of Total Production of Cottonseed in India Calculated with a Common Ginning Percentage of $33\frac{1}{3}\%$ and Calculated with Individual Ginning Percentages of the Different Varieties, during the Years 1953-54, 1954-55 and 1955-56

Year	Total production estimated with a common ginning percentage ($33\frac{1}{3}\%$) in '000 tons	Total production calculated on individual ginning percentages in '000 tons
1953-54	1388	1376
1954-55	1504	1671
1955-56	1399	1335

TABLE II

Number of Samples of *Desi* and American-type Seed Obtained and Analysed from Different States in India During the Season 1951-52 to 1956-57

State	No. of *desi*-type samples	No. of American-type samples	Total number of samples
Andhra	78	14	92
Bombay	74	22	96
Hyderabad	26	9	35
Madhya Pradesh	19	4	23
Madhya Bharat	21	15	36
Madras	31	70	101
Mysore	24	42	66
Pepsu	4	4	8
Punjab	10	24	34
Rajasthan	17	27	44
Saurashtra	8	1	9
Uttar Pradesh	19	4	23
Total ...	331	236	567

The number of samples obtained and analysed of the more important varieties throughout the country, together with the seed production of that variety, is given in Table III.

TABLE III

Number of Samples of the More Important Varieties of Seed Analysed and their Production During 1957-58

Name of variety	No. of samples analysed	Production of variety during 1957-58 ('000 tons)	Geographical region of production
Madras American (Cambodia, MU & MCU) ...	72	90.3	Madras
Lakshmi	45	39.7	Andhra & Mysore
Mysore American (M.A. 5 & M.A. 2) ...	26	49.7	Mysore
Punjab & Rajasthan Americans (H14, 216F, 320F, LSS, C-Indore-1)	57	189.7	Punjab & Rajasthan
Broach-Vijay (including Vijalpa & 1027 ALF) ...	35	94.0	Gujerat and Cutch
Jarila (including Virnar, 197/3)	32	186.2	Madhya Pradesh & Bombay
Buri (including Indore-2)	20	29.2	Madhya Pradesh
Karunganni	17	51.1	Madras
Uppam-Tinnies	12	33.5	Madras
Jayadhar-Jayawant	17	51.1	Mysore
Gaoranis	24	83.8	Andhra Pradesh & Bombay
Malvi (including Bhoj, Gwalior 16 & M.P. (*Desi*) ...	20	84.5	Madhya Pradesh
Punjab *Desi*	15	85.9	Punjab
U. P. *Desi* (including 35/1-inch)	19	13.2	Uttar Pradesh
Rajasthan *Desi* (including C 520, G1, & Pratap) ...	19	50.0	Rajasthan
H 420	6	52.1	Madhya Pradesh
Dholleras (Kalyan, Wagad, Kalagin, Nathio) ...	13	131.6	Gujerat & Cutch
Surti-Suyog	1	48.7	Bombay
Hingari or H1 or Westerns or Farms	21	14.8	Andhra Pradesh & Mysore
Northerns	10	5.5	Andhra Pradesh
Mungari	9	17.1	Andhra Pradesh
Andhra *Desi* (Chinnapathi, Cocanadas, Umri, etc.)	37	10.7	Andhra Pradesh
Total ...	527	1412.4	

A summary of the data on the composition of *desi* and American-type seed is given in Table IV for the various characteristics determined. The more important characteristics of the samples, *viz.* oil, linters and protein contents, have been calculated on a common basis of 10% moisture, since the average moisture content of 7.8% found for both *desi* and American seed is nearer to 10% than to 5%. This will also afford an easy comparison of the composition of Indian cottonseed with that of seed in the U.S.A. which is the largest cottonseed-producing country in the world and that where the industry is developed most. The data is presented in Table V.

TABLE IV

Composition and Characteristics of 331 Samples of *Desi* and 236 Samples of American Varieties of Indian Cottonseed (on "as is" basis)

Characteristics	*Desi* varieties		American varieties		Average of all varieties Per cent	Cottonseed in U.S.A.	
	Limits Per cent	Average Per cent	Limits Per cent	Average Per cent		Limits Per cent	Average Per cent
Foreign Matter * .	0.8-3.4	1.9	0.3-3.8	1.6	1.8	...	...
Moisture	3.3-13.9	7.8	2.1-13.6	7.8	7.8	6.5-20.0[a]	11.3[b]
Linters	1.0-16.1	5.8	1.7-17.9	10.3	7.7	3.0-18.0[c]	10.0[c]
Oil	12.5-24.8	17.7	13.6-24.5	18.3	18.0	...	18.6[b]
F.F.A. of oil in seed ...	0.6-12.5	2.0	0.4-8.6	2.1	2.0	0.5-9.6[d]	1.3[b]
Protein †	13.7-26.9	17.9	17.2-25.0	19.8	18.6	14.0-31.0[a]	23.1[e]
Seed size in mm. ...	4.3-9.6	...	5.0-11.4	...	4.3-11.4	8.0-12.0[f]	...
Seed Index (Wt. of 100 seeds in gms.) ...	3.9-9.4	5.5	4.7-12.6	8.0	6.7	...	11.1[d]
Hulls ††	36.3-50.9	44.5	30.8-42.7	37.9	41.2	40.83-48.2[h]	44.04
Kernels ††	46.0-54.8	50.7	45.8-60.4	51.2	51.0	51.74-59.17[h]	55.96
Hull-Kernel ratio ††	0.74-1.07	0.88	0.51-0.93	0.74	0.80	...	0.79
Oil content of kernels ** ...	25.2-36.4	29.4	28.0-35.8	31.8	30.3	31.91-38.35[g]	35.40
Kernel size in mm. ††	3.9-6.5	2.7	5.1-8.0	...	...	...	...
Kernel Index (wt. of 100 kernels in gm.) ††	2.1-3.6	2.7	2.9-6.5	4.3	3.5	...	...
Sap. value of oil in seed ***	189.0-201.0	194.0	189.0-196.0	192.0	193.0	190-198[i]	...
I.V. of oil in seed ***	91.0-111.0	101.0	94.0-110.0	100.0	101.0	100-112[j]	...
Gossypol contents of †††							
(a) seed	0.48-0.82	0.62	0.43-0.88	0.65	0.63	0.44-0.76[k]	...
(b) hulls	0.0010-0.0021	0.0015	0.0008-0.0009	0.0009	0.0012	...	
(c) Kernels ...	0.90-1.68	1.20	0.94-1.54	1.22	1.20	0.39-1.70[l]	...

* For 26 *Desi* and 18 American-type samples.
† On dry basis (for 44 *Desi* & 29 American-type samples.)
†† For 20 *Desi* & 20 American-type samples.
** For 11 *Desi* & 7 American-type samples drawn from kernels in pilot-plant runs.
*** For 19 *Desi* and 15 American-type samples.
††† For 11 *Desi* and 7 American-type samples.
a. Cottonseed and Cottonseed Products, edited by a A. E. Bailey, 1948, p. 504.
b. Agricultural Information Bulletin No. 39 ("The Grading of Cottonseed") 1951, United States Department of Agriculture.
c. Ref. a, p. 555, 137;
d. *Ibid*, p. 518;
e. *Ibid*, p. 137, (moisture-free basis);
f. *Ibid*, p. 105;
g. *Ibid*, p. 134;
h. *Ibid*, p. 136;
i. *Ibid*, p. 386;
j. *Ibid*, p. 385;
k. *Ibid*, p. 311;
l. Pons, W. A. Jr. *et al.* J. Agr. & Food Chem. 1, 1115-18 (1953).

TABLE V

Lint and Oil Contents of 331 Samples of *Desi* and 236 Samples of American Varieties of Cottonseed on 10% Moisture Basis

Characteristics	*Desi* varieties		American varieties		Cottonseed in U.S.A.	
	Limits	Average	Limits	Average	Limits	Average
Linters %	1.0—14.1	5.5	1.6—16.1	9.8	...	11.4[a] 13.2[a]
Oil %	12.6—24.4	17.8	14.0—22.8	18.3	...	17.7[a] 18.4[c] 19.2[d]
Protein %	12.3—24.2	16.3	15.5—22.5	18.0	..	20.8[c]

a. Cottonseed and Cottonseed Products, 1948, p. 119, 137.
b. *Ibid*, p. 516.
c. "The Grading of Cottonseed" Agricultural Information Bulletin No. 39, 1951, p. 48.
d. Cottonseed and Cottonseed Products, 1948, p. 137.

In Table VI is given the analysis of oil and linter contents of 231 samples of *desi* and 236 samples of American varieties of seed on an "as is" basis.

TABLE VI

Analysis of the Oil and Linter Contents of 331 *Desi* and 236 American-type Cottonseeds

Limits of Linters or Oil contents	*Desi* varieties		American varieties	
	No. of samples analysed	Per cent of samples analysed	No. of samples analysed	Per cent of samples analysed
OIL				
Below 15%	25	7.5	6	2.6
15.0 to 17.4%	128	38.8	61	25.8
17.5 to 19.9%	150	45.4	120	51.1
20.0% and above	28	8.4	48	20.8
Total ...	331	100.0	235	100.0
LINTERS				
Below 3.0%	47	14.1	2	0.9
3.0 to 4.9%	106	31.7	7	3.0
5.0 to 7.4%	104	31.7	29	12.1
7.5 to 9.9%	51	15.9	99	42.2
10% and above	23	7.0	98	42.2
Total ...	331	100.0	235	100.0

Oil Contents of Indian Cottonseed

The data given in Tables IV and V, and particularly in VI, on the oil contents of the Indian cottonseed reveal some interesting features.

(i) The average oil content of *desi* seed in India is 17.8% for the 331 sample while that of 236 samples of American seed is 18.3% (Table V), on a 10% moisture basis. The same difference in the oil content is revealed on an "as is" basis also (Table IV).

(ii) The American seed contains 15% or more oil in 97.6% of the samples analysed. When this is calculated production-wise for American variety seed, the figures average 97.5% the individual annual percentages being 97.3, 97.6 and 97.6 respectively for the years 1953-54, 1954-55 and 1955-56. In the case of *desi* seed, 92.4% of the samples analysed contained 15% or more oil, the corresponding production-wise figures being 94.1% (average) and 94.6%, 94.7% and 93.1% for the above three individual years respectively. It will also be seen that the data obtained on the oil contents of 15% or more, sample-wise (which is actually done), corresponds closely to the values obtained when calculated on the production-wise basis, for both *desi* and American varieties.

(iii) From the above figures, it is seen that a large per cent (75%) of the *desi*-type seed produced in India contains a high percentage of oil, comparable with that of the American-type seed being crushed preferentially at present for oil in India. This observation becomes all the more significant if it is borne in mind that about 70% of the production in the country at present is *desi* seed. It is relevant to mention in this connection that, while the price of the American-type seed used to be considerably lower in earlier years, for the last two years the difference has considerably narrowed down.

(iv) The industry will naturally be interested to know which particular *desi* and American varieties of cottonseed contain a high percentage of oil, so that they may use them for processing. This data is given in detail in our paper entitled "Varietal Characteristics of Indian Cottonseed" which is also being presented at this Symposium. However, I may mention here that varieties of high oil content among American-type seed are C-Indore (23.0%), LSS (22.0%), 320 F(21.3%), Raj (21.6%), and Buri (21.5%), closely followed by Parbhani American (20.6%), Lakshmi (20.4%), H14 (20.1%) and MU and MCU (19.9%), the figures in brackets giving average oil content on a moisture-free basis. Of the *desi*-type seed, the high oil content varieties are Punjab *Desi* (21.0%), Ganganagar (or G1) (20.8%), Chinnapathi, Coconadas and Desavali (not major varieties) of Andhra (19.6%), Virnar (19.3%), Gaoranis (19.7%), Malvi (19.9%), Vijay (19.5%), Jarila (20.1%), Rajasthan *Desi* (19.8%), H 420 (19.7%), Pratap (19.6%) and 2204 (Daulat) (19.4%), closely followed by Hingari (Farm) and Mungari (18.8%), Uppam-Tinnies (18.9%) C-520 (18.7%), Vijalpa (18.6%), U.P. *Desi* (18.9%), Dholleras (Kalyan, Wagad, Kalagin, and Mathio) (18.2%), Karunganni (18.0%) and Jayadhar-Jayawant (17.5%).

Linter Contents of Indian Cottonseed

The data on the linter contents given in Tables IV, V and particularly VI, also reveal the following interesting features.

(i) The average linter contents of the *desi* seed (331 samples is 5.8% and that of American-type seed (236 samples) is 10.3% on an "as is" basis. Practically the same levels of linter contents is shown on a 10% moisture basis. Thus, while the linter content of American seed is much higher than that of *desi* seed in India, *desi* seed too has many varieties carrying a high per cent of linters. This data does not substantiate the view expressed by earlier workers[4] that *desi* seed is practically naked nor that expressed even recently that the delinting of the *desi* seed (low residual-linters type) "may well be unnecessary and economically wasteful."[5]

(ii) From the data given in Table VI, it will be seen that about 55% of the samples of *desi* seed analysed contain 5% or more of lint and further that 23% of the samples analysed contain 7.5% or higher. 32% of the samples analysed contain between 3.0-4.9% linters. In American seed, 96% of the seed samples analysed contain 5.0% or higher, 81% containing 7.5% or more; only 5% of the samples analysed contain below 5.0%. These figures reveal strikingly the difference regarding this characteristic between *desi* and American-type seed. When the production-wise figures are calculated from these sample-wise figures for the 3 years 1953-54 to 1955-56, it is found that, on the average, 53.0% of the *desi* seed produced contain 5.0% or more of linters, the annual figures for the 3 years being 55, 51 and 53% respectively. For American-type seed, the corresponding production-wise figures for seed containing 5% or more of linters work out to 91% (average) and 92, 90 and 91% for the 3 years respectively. Therefore, it is quite necessary to delint not only all the American-type seed processed but also *desi* seed to the extent of about 55% of the production, in order to improve the quality and quantity of oil and cake produced. In this connection, I would like to add that the production-wise percentages of the different linter contents given above are only approximate, as the calculations are complex and based on some assumptions. The most important assumption is that the number of samples of each variety analysed is quite adequate and proportional to the relative production of that variety, which is not true of all the varieties studied.

(iii) As for individual varieties of *desi* and American-type seed that have high linter contents and their production in India, this aspect is also discussed in detail in our paper on the "Varietal Characteristics of Indian Cottonseed," referred to above. Among American-type seed these are Raj (14.0%), Parbhani American (13.9%), 134-CO2-M(12.3%), H 14 (12.7%), M.A. (12.2%), Cambodia (12.0%), 216 F (11.7%), Lakshmi (11.5%), and Madras Uganda (11.3%) varieties. Among *desi*-type seed these are Mathio (12.3%), Suyog-Surti (11.4%), Uppam-Tinnies (10.5%), '35/1' (10.4%), 1027 ALF (10.7%), Rajasthan *Desi* (8.4%), Karunganni (7.8%), Malvis (6.5%), Punjab *Desi* (6.5%), H 420 (6.4%), Jarillas (6.6%), Kalyan (6.2%), U.P. *Desi* (6.2%), M.P. *Desi* (5.7%), Wagad (5.4%) and Gaorani 12 (5.1%) varieties. The values in brackets are average figures on a moisture-free basis.

Protein Contents

The protein contents of the seed on a dry basis are given in Table IV and on a 10% moisture basis in Table V. It is obvious from this data that the protein content of *desi* seed is less than that of American-type seed, which in turn is considerably less than that of cottonseed in the U.S.A. The average protein content of both types of the Indian seed (18.6%) is also considerably lower than the average protein content of the seed in America. From this, it follows that the protein contents of the decorticated cottonseed cakes produced in India will be considerably lower than those produced in the U.S.A., the more so in *desi*-type cake than in American-type cake.

Gossypol Contents

The gossypol contents of 11 varieties of *desi* seed and 7 varieties of American seed and their individual kernels and hulls, determined at Oil Technological Institute, are given in Table IV. For comparison, the gossypol contents of the whole seed and uncooked kernels found in the U.S.A. are also given, and are of about the same order as those in Indian seed. However, the upper limit of the gossypol contents of seed from Russia (at present the second-largest cottonseed-producing country in the world) appear to be considerably higher, varying from 0.15 to 1.59%.[6] According to Narayana Rao and Krishnamurty[7] the gossypol contents of the seed and kernels of 3 American and 6 *desi* varieties varied from 0.72-0.92% for the seed and 1.56-2.35% for the kernels. It may be noted that the hulls too contain traces of gossypol.

The data obtained so far on the gossypol contents of Indian seed and its component parts are not adequate enough to draw any general conclusions, and further studies on this aspect are in progress at the Oil Technological Institute, Anantapur.

Seed Size and Seed Index

From the data obtained on these characteristics for the 567 samples (Table IV), it is found that *desi* seed has a definitely smaller size and seed index than American-type seed, which in turn is smaller than seed in the U.S.A. The average seed index of U.S.A. seed is double that of *desi* seed and nearly 1.5 times that of American-type Indian seed. The significance of this data is that the screens recommended and used for cleaning and for separation after hulling for American seed will be unsuitable for use with *desi*-type seed and to a lesser extent even for American-type Indian seed. It is also experienced that due to the admixture of *desi* seed to the extent of 10-20% with American-type seed in India, as obtained in the markets, delinting cannot be done uniformly nor the separation of uncut seed from the meats after dehulling.

Hull and Kernel Contents, their Ratio, Kernel Size and Kernel Index

The data obtained for these characteristics on 20 samples each of *desi* and American seed, representing 25 varieties (12 American and 13 *desi*) in all, is given in Table IV. Although the number of samples studied is not quite sufficient and more are being studied, the results obtained so far show that the hull contents (without lint) of *desi* seed varies from 36.3-50.9%, with an average of 44.5%; this is greater than that for the American-type seed, which varies from 30.8-42.7%, with an average of 37.9%. But the kernel contents are found to be of the same order for both types of seed: for *desi* seed the limits are 46.0-54.8%, with an average of 50.7%, and for American-type seed, the limits are 45.8-60.4%, with an average of 51.2%. A value of 60.4% for kernels was found in only one out of the twenty samples of American seed analysed, the next highest value being 53.1%. The average hull-kernel ratio is higher for *desi* seed (0.88) than for American seed (0.74). On the other hand, if hull content with linters on is taken into account, the average values for hull contents and hull-kernel ratio for both the types of seed are approximately the same, hull contents being 49.4 and 48.8% and the hull: kernel ratio 0.97 and 0.95 respectively for *desi* and American-type seed.

The size and index of *desi* seed kernels are lower than those of American seed; the difference in this characteristic for the two types of seed has a practical bearing for the industry, namely that both in the dehulling and the following separation stages, different adjustments of huller plates and different size screens have to be made.

Narayana Rao and Kuppuswamy[8] reported the hulls and kernel contents of 3 American and 6 *desi* varieties of seed on an "as is" basis and Harwalker *et al.*[5] reported on 2 American and 8 *desi* varieties on a dry, delinted basis. The former reported that the hull content (without linters) varied from 36.2-44.4% and kernels from 44.4-50.8%. The latter reported that they varied respectively from 37.6-47.0% and from 53.3-62.4%.

Effect of Varietal, Climatic, Environmental and Maturity Factors on the Composition of Cottonseed

We have studied the composition of the large number of cottonseed varieties produced in India from the varietal point of view to a fairly good extent. Further studies in this regard are in progress. The details of the results obtained on these aspects are given at some length in another paper on varietal characteristics sent to this Symposium.

We have studied and reported[9] the effect of the maturity factor on the composition of cottonseed with reference to the oil and linter contents, size of the seed and F.F.A. of the oil in the seed. It was indicated to some extent that oil content slightly increased with advanced picking. But in the other aspects studied, no particular trends were observed. However, we feel that extensive and specific studies on this aspect are required to be made before arriving at any definite conclusion on the influence of maturity not only on the oil content but also on other fundamental characteristics of cottonseed.

We tried to collect climatic and environmental information on the samples sent to us from the sources which supplied them but not with any measure of success. There is a great and urgent need to undertake work on the fundamental characteristics of all varieties of cottonseed as influenced by climatic and environmental conditions in the different regions of India, from year to year. Such work requires close collaboration and liaison between technological, agricultural and meteorological departments, as is done in the U.S.A.

Some Physical and Chemical Characteristics of Indian Cottonseed Oils

In the course of our laboratory and pilot-plant work, we have studied some of the physical and chemical characteristics of the cottonseed oils produced. The saponification and iodine values of these are given in Table IV. The specific gravity at room temperature was determined on 20 different oils obtained from *desi* (9 varieties) and American (3 varieties) seed. The values for *desi* seed oil (13 samples) varied from 0.9020 to 0.9228, with an average of 0.9138, and those for American seed oils (7 samples) varied from 0.9116-0.9202, with an average of 0.9154. The colours of 18 different crude oils produced by the modern process (11 oils from 9 *desi* varieties and 7 oils from 3 American varieties) were also measured on the Lovibond Tintometer, after diluting with a high B.Pt. petroleum solvent. The colour, expressed as Y plus 10R units, varied from 191.5-700.5, with an average of 331.0 units for the *desi* seed oils and for American seed oils it varied from 176.0 to 684.0 with an average of 341 units. This data indicates that the variation in the colour of crude Indian cottonseed oils is dependent not so much on the type of *desi* or American seed as from which it is produced, as on the history of the seed and conditions of processing.

34 samples of oils from 20 *desi* and 14 American seed samples from Madras, Bombay, Rajasthan, Madhya Pradesh and Punjab States have been analysed for iodine and saponification values.[10] The I.V. of *desi* seed oils varied from 91.0-111.0, with an average of 101.0 and those of American seed from 94.0-110.0, with an average of 100.0. 26 out of these 34 values of I.V. are less than 104. Revision of the I.S.I. specification in the light of these values is clearly indicated. The saponification values of oils from the same cottonseed samples (*desi* and American) as above were also determined. The saponification values of oils in *desi* seed varied from 189.0-201.0, with an average of 194.0, and those of oils from American seed varied from 189.0 to 196.0, with an average of 192.0.

The gossypol contents of 16 samples of crude oils obtained in an expeller were determined.[11] The gossypol contents of 7 samples of *desi* seed oils varied from 0.05-0.66%, with an average of 0.36% and those of 9 samples of American seed oils varied from 0.04-0.80%, with an average of 0.37%. The values obtained by other workers[7] are from 0.39-0.47%, with an average of 0.34% for 6 samples of oils from *desi* seed, and from 0.38-0.42% with an average of 0.40% for 3 samples of oils from American seed (all hydraulic-pressed oils). These average values from the two laboratories show that there may not be any appreciable difference in the gossypol contents of *desi* and American-type oils.

The Phosphatide Contents of Cottonseed Oils

The phosphatide contents of freshly-produced cottonseed oils and cakes are found in the course of our investigations to be the highest among the major Indian vegetable oils and their cakes.[12,13] The phosphatide contents of one *desi* whole seed (Jayadhar) was found to be 0.639% and of one American seed (Lakshmi) to be 0.794%. The phosphatide contents of the hulls of the above two seeds were respectively 0.125% and 0.110%. The phosphatide contents of 25 different samples of cottonseed oils, including 17 trade samples, were found to vary from 0.46-2.74%, with an average of 1.73%, and in the case of 16 samples, including 8 trade samples, of cakes, to vary from 0.77 to 1.54%, with an average of 1.13%. For these, the recovery in the laboratory as acetone-insolubles by degumming the oils varied from 59.8-98.3%with an average of 80%, and for the cakes from 60.0 to 98.5% with an average of 86.3%.

The above data obtained in our Institute is clearly indicative of the possibility of commercially recovering the industrially important product, commercial lecithin, by introducing suitable steps in the processing of the oil and cake.

Cottonseed By-products

(a) *The cake.* The composition and quality of cottonseed cake depends upon the processing method by which it is produced. It is broadly classified as decorticated or undecorticated cake depending upon whether it has been produced by the modern process or by crushing the whole seed, with or without delinting in the latter case. The decorticated cake is undoubtedly the more nutritious of the two, as it contains a higher protein or protein plus fat content and less fibre and free gossypol than the undecorticated cake. However the survey made by the Hindustan Lever Ltd.,[14] shows that undecorticated cake is more popular with the cattle feeder than decorticated cake. It, therefore, seems necessary to educate the cattle feeder regarding the superior nutritive value of decorticated cake.

I may state here that in India, till now, cottonseed cake has been fed only to ruminants, while in the U.S.A. swine and poultry are also served with rationed amounts of cottonseed cake. For the latter a low "free" gossypol content of the cake is necessary. While gossypol is not toxic to ruminants, it is toxic to animals with simple stomachs like man, swine, poultry, etc. We have determined the free gossypol contents of 11 samples of oilcakes produced in our pilot-plant work and 4 samples of decorticated cakes produced in the actual industry. It was found that the free gossypol contents of oilcakes from *desi* seed varied from 0.031-0.061%, with an average of 0.04%, and those of American-type seedcakes from nil to 0.06%, with an average of 0.034%. Though the above values compare favourably with those observed in cakes in U.S.A. (0.028-0.084%),[15] there is need to maintain a low free gossypol in our Indian cottonseed cake by proper processing.

(b) *Linters and Hulls.* A few characteristics of these were determined by us. The moisture contents of the seeds and the corresponding whole hulls and meats for 20 samples were studied. It was found in all cases that the moisture contents of the hulls with linters is the highest, that of the whole seed intermediate and of the kernels lowest, showing that moisture is not distributed evenly throughout the cottonseed. The oil contents of delinted hulls obtained in pilot-plant work, after removal of the meats sticking to the linters by shredding from a 20 mesh sieve, varied from 0.93-2.88%. Apparently this high oil content of hulls, compared to the 0.5-0.9% of oil observed in the U.S.A. is partly due to the fine meat particles still sticking to the hulls. The F.F.A. of the oils from the hulls varied from 26.3-59.1%, which is very much higher than the F.F.A. of the oil in the corresponding meats, which varied from 1.2-6.1%.

The moisture and oil contents and F.F.A. of oil in the linters were also studied in a few cases. The moisture content varied from 2.6-7.7% compared to the corresponding moisture content of 5.4-9.1% for the whole seed. The oil content of linters varied from 1.0-2.1% compared to the limits of 0.74-1.00% found as ether extractives in the U.S.A.[16] The F.F.A. of the oil in these linters varied from 7.5-61.6% compared to those of the oil in the corresponding kernels varying from 2.9-9.0%. As the oil and moisture contents and the F.F.A. of the oils in the hulls and linters have a bearing in arriving at the material balances and oil balances, as well as the quality of these products in plant processing, it appears necessary that a more thorough and systematic study of the above aspects has to be made.

Technological Aspects of the Study of the Composition and Characteristics of Cottonseed

From the above, it is clear that a systematic study, in sufficient numbers, on the composition and characteristics of different varieties of Indian cottonseed and their component parts have an important bearing from several standpoints on the processing of the cottonseed. Firstly, it will enable the industry to select a variety of the seed available in particular regions, more economical to crush than the others. Secondly, it will enable the industry to know in advance approximately the quality and quantity of the oil, cake and other byproducts that could be obtained by crushing particular varieties of seed. Thirdly, it will guide the industry in respect of the modifications to be made in the pretreatment equipment at different stages, as pointed out in the foregoing discussion. A preliminary analysis of the seed produced in the season will enable its grading into prime, off-grade, etc., for purposes of purchase and processing, as is done invariably in U.S.A. and in the case of groundnut in India itself. If done, this will prove advantageous both to the farmer and to the miller.

Acknowledgment

I acknowledge with thanks the assistance given by Sri S. D. Thirumala Rao and Sri B. Appu Rao, Senior Scientific Assistants of this Institute, in preparing this paper. My thanks are also due to the Directors of Agriculture of the various States and their Departmental Officers whose co-operation and help enabled us to obtain during the past several years the large number of representative samples of cottonseed, data on which is presented in this paper.

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2. COMPOSITION AND UREA SEPARATION OF FATTY ACIDS FROM INDIAN COTTONSEED OILS

By

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The Indian cottonseed oils studied contain 22% saturated acids, and either 36% oleic—42% linoleic, or 42% oleic—36% linoleic acid contents. The products obtained from cottonseed fatty acids by adduction with urea using various techniques are described; some aspects of urea adduction on a large-scale are discussed.

A. FATTY ACID COMPOSITION

Data on the fatty acid components of Indian cottonseed oils are fundamental to their utilisation. The results of analysis of several samples by the lead salt-ester fractionation technique were published in 1953 by Harwalkar, Achaya and Saletore.[1] This data, together with one subsequent unpublished analysis from this laboratory[2] and comparative earlier data, is reproduced in Table I.

TABLE I

Fatty Acid Composition of Cottonseed Oil

	Nanded (Gaorani 6)	Latur (G. 12F.2)	Adilabad (American Parbhani)	Market samples (Unknown origin)		Literature figures	
				1	2	Range	Average
Oil							
S. E.	292.1	292.5	286.3	297.3	292.0	...	...
I. V.	105.3	109.0	103.3	102.8	103.5	90—117	105
Acid value	3.6	0.6	20.5	0.5	...	...	...
Component fatty acids (% wt.)							
Myristic	1.3	1.3	2.3	0.9	0.5	0—3	1
Palmitic	17.2	17.1	19.5	16.9	23.7	19—23	22
Stearic	0.9	2.0	0.9	3.2	2.4*	1—3	1
Hexadecenoic	2.5	1.3	0.8	...	2.6	—	1
Oleic	44.2	41.4	34.8	36.4	26.4	18—36	28
Linoleic	33.9	36.9	41.7	42.6	44.4	34—57	47

* Includes 0.8% arachidic acid.

Conclusions from Table I

1. The saturated acids, comprising mostly palmitic, amount to 20-22% which is about 3-5% lower than the corresponding published figures for American cottonseed oils.

2. In regard to the unsaturated acids oleic and linoleic, oils from American-type seeds are richer in oleic (36%) and poorer in linoleic (42%) than corresponding American oils (average 28 and 47% respectively), while the seed from *desi* cottonseed is more saturated still and indeed an oleic-rich oil (42% oleic, 36% linoleic).

3. Generalisation is premature on the basis of so few analyses, the more so since an Indian sample of unknown origin analysed very close to the average U.S.A. type.

4. The results support the now well-known phenomenon that plant, animal and fish fats from any species raised in tropical climate are more saturated than fats from some species raised in cooler climates. Zaheer and Achaya[3] have discussed the causes for this with suitable illustrations.

5. The higher degree of saturation of Indian cottonseed oils "are not without technological bearing.[1] The large mass of data accumulated in America on the composition of partly-hydrogenated cottonseed oil products must be applied cautiously in India, since the starting materials are now shown to be so widely different. Again, the segregation of highly-unsaturated glyceride fractions from cottonseed oil by liquid-liquid extraction and low-temperature crystallisation will not be capable of duplication with Indian oils; different proportions of fractions, of probably lower degrees of unsaturation, are anticipated."

B. UREA SEPARATION OF COTTONSEED MIXED FATTY ACIDS

The usual methods of separating fatty acids are by crystallisation from solvents or by fractional distillation of acids (commercial) or esters (in the laboratory). The crystallisation method easily separates saturated from unsaturated acids, but for separation of oleic or linoleic acids among themselves, very low temperatures, which have so far been only feasible in the laboratory, are necessary. Distillation will separate saturated acids of different chain lengths but not acids whether saturated or unsaturated of the same chain length, like stearic, oleic and linoleic.

The urea technique depends on the fact that when urea encounters a long, straight-chain molecule of 12 or more carbon atoms in length, it wraps itself around the latter to form a crystalline complex which is thrown down as a white powder that can be filtered off, and resolved again by throwing into water into the adducted fatty acids and urea (in aqueous solutions). A certain degree of selectivity is shown by urea in the decreasing order saturated, oleic and linoleic acids, while the phenomenon is a purely relative one and liable to the unpredictability of mutual co-precipitation of acids. Urea will react with fatty acids in solution or suspension in solvents like methanol and ethanol or even as a solid.

In studies since about 1951, the resolutions possible with the mixed fatty acids of several oils were studied[4] and the results with cottonseed oil fatty acids are given in this paper. Good resolutions are obtained by an initial urea resolution of the mixed fatty acids, followed by subsequent re-resolution of the primary precipitated and soluble fractions, resulting in all in four final fractions, and this technique has been followed throughout. The urea was used:

(1) As a saturated solution (about 20%) in methanol.

(2) As a saturated solution (also about 20%) in 80% ethanol.

These results are shown in Table II.

TABLE II

Resolutions of Cottonseed Mixed Fatty Acids Using Urea in Saturated Solution

Technique	Urea—Methanol		Urea—80% Ethanol	
	Refluxing & cooling		Refluxing & cooling	
Fraction	%	I.V.	%	I.V.
A	25	31	17	17
B	20	101	21	75
C	18	126	18	100
D	37	166	44	152

(3) As a solid, in the presence of 5 parts of 95% ethanol. In all the cases covering Items 1 to 3 above, the solutions were refluxed for an hour, cooled overnight and then worked up.

(4) As a solid, the fatty acids being taken in 8 parts of 80% ethanol, the solid urea added, the slurries stirred for 15 minutes in the cold and the precipitated adducts rapidly filtered and worked up.

The results of Items 3 and 4 are shown in Table III.

TABLE III

Resolutions of Cottonseed Mixed Fatty Acids Using Urea as Solid

Technique	Adduction by boiling						Cold adduction		
	Fatty acids in 2 parts 95% ethanol, urea added, refluxed and cooled						Fatty acids in 8 parts 80% ethanol, solid urea added, stirred 15 minutes in the cold		
	Method 1			Method 2					
Parts of urea used for initial resolution, and p.p.t. and sol. readduction, respectively	1.5	2	2	1	2	1	3	2.5	4
Fraction	%		I.V.	%		I.V.	%		I.V.
A	25		40	14		24	29		15
B	24		96	18		78	21		72
C	24		107	19		93	25		127
D	27		166	49		144	25		158

Conclusions from Tables II and III

1. Urea adduction is to a considerable degree a relative phenomenon. Thus the once-precipitated fraction, on re-adduction, will precipitate again partially and selectively, even though enough urea is present for complete adduction. Similarly the soluble fraction, on further addition of urea, will yield a precipitate.

2. The various methods used may be compared. Urea in saturated methanol is very selective at the unsaturated end of a separation, giving a large fraction (37%) of high I.V. (166, cf. 181 for pure linoleic acid) and is recommended for laboratory work. The slurry-adduction method in the cold using solid urea has been successful at the saturated end, giving most of the saturated (palmitic) acid with a very low iodine value of only 15, which is quite remarkable for a non-distillation technique. The solid urea method is extremely flexible and can easily be adjusted to give quite a range of products.

3. The fatty acid fractions can be considered for most utilisation purpose to be almost pure fatty acids, which are in increasing use. Fraction A is almost pure saturated, *i.e.* palmitic acid useful in soap making; fractions B and C are mostly oleic acid useful in lubricants, carbon paper, etc., while fraction D is a rich linoleic concentrate of great value in alkyds or for essential fatty acid therapy.

4. Some considerations bearing on large-scale separation of fatty acids by the urea adduct technique may be mentioned. Its primary advantage over existing methods of crystallation and distillation is that it will resolve partly though not completely oleic and linoleic acids, as illustrated by fractions C and D. Of the various methods tried, the cold slurry-adduction method is likely to find favour for large-scale fatty acid resolution, since it involves no heating and is so rapid (15 minutes) that almost continuous operation is possible. Large volumes of solvent alcohol are necessary; saturated fractions tend to crystallise if the solvent volume is reduced. In fact, the inflated bulks to be handled constitute the greatest disadvantage of urea separations over distillation. In laboratory experiments the alcohol employed is recovered to the extent of 85%; in large-scale work this will be higher. To obtain complete release of fatty acids from the adduct, it is necessary to decompose it not with water but with 1% hydrochloric acid. The urea obtained by evaporating the slightly acid solution is re-usable (and in fact more active than the original urea), and is of course fully recovered. Pilot-plant working data for urea separation of petroleum has been reported in one communication in the United States and it is also believed to be used commercially. None is available for fatty acids. The economics of the process can only be obtained by pilot-plant working which is proposed to be soon undertaken. The fatty acids needed in large quantities for the work will be derived from the fat splitting unit soon to be installed in this laboratory as part of the 100 kg./batch fatty acid distillation plant. It is hoped eventually to couple the urea technique with standard processes of solvent crystallisation, hydrogenation and fatty acid distillation, and thus obtain a range of fatty acids both saturated and unsaturated.

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3. NUTRITIVE VALUE OF CRUDE, REFINED AND HYDROGENATED COTTONSEED OIL

By

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1. No significant difference was observed between the growth promoting value of diets containing 10% of crude, refined and hydrogenated cottonseed oil, refined groundnut oil and cow's ghee.

2. Crude, refined and hydrogenated cottonseed oils were found to be digestible to the extent of 95-98% in the rat.

3. About 70-75% of calcium and 65-70% of phosphorus was utilized in the case of rats fed on diets containing 10% of crude, refined and hydrogenated cottonseed oils.

Introduction

In recent times considerable interest has been evinced in the utilization of cottonseed oil for edible purposes. Crude cottonseed oil, obtained by expressing steamed cottonseed kernels, has a dark-brown colour and contains gossypol which has toxic properties.[1] Consequently and unlike groundnut, coconut and gingelly oils, cottonseed oil cannot be used for edible purposes without preliminary refining. In addition to its use as a salad oil, cottonseed oil is also hydrogenated and used in the preparation of shortenings and margarine.[2] Although a large amount of work has been done on the digestibility and nutritive value of a wide variety of edible oils, little information is available concerning crude, refined and hydrogenated cottonseed oil. The present paper deals with studies on (i) the digestibility of crude, refined and hydrogenated cottonseed oil and (ii) the effect of incorporation of crude refined and hydrogenated cottonseed oil on the growth and calcium and phosphorus metabolism of young rats.

EXPERIMENTAL

Materials

Crude cottonseed oil used in this study was prepared by hydraulic pressing of steamed cottonseed kernels. Refined cottonseed oil was prepared by refining and re-refining the crude oil according to the procedure of Narayana Rao and Kuppuswamy.[3] Hydrogenated cottonseed oil (m.p. 37°C) was supplied by Hindustan Vanaspathi Manufacturing Company. All the experimental fats and oils were fresh and pure. Their physical and chemical constituents were determined according to A.O.C.S.[4] Methods (Table I).

Digestibility of Crude, Refined and Hydrogenated Cottonseed Oil

The *in-vitro* digestibility of crude, refined and hydrogenated cottonseed oils was studied using castor seed and pancreatic lipases according to the procedure of Ahmed and Sareen[5] and Weinstein and Wynne.[6] The relative rates of hydrolysis of different oils and fats are presented graphically in Fig. 1 and Fig. 2. The results of *in-vitro* studies show that the course of hydrolysis of cow's ghee is significantly different from that of other fats. This finding confirms the earlier observation of Narayana Rao and Swaminathan[7] and Dastur and Giri.[8] The hydrolysis of the other fats studied follow nearly the same course.

TABLE I

Analytical Characteristics of Experimental Fats

Fat	m.p. °C.	Sap. value	Iod. value	SCN value	Acid value
Crude cottonseed oil	Liquid at room temp.	188.0	100.5	59.0	2.05
Refined cottonseed oil	Liquid at room temp.	194.5	102.6	60.3	0.58
Hydrogenated cottonseed oil	37	189.0	69.0	...	0.58
Refined groundnut oil	Liquid at room temp.	188.0	90.6	62.0	0.05
Cow's ghee	33	220.0	32.9	26.3	0.21

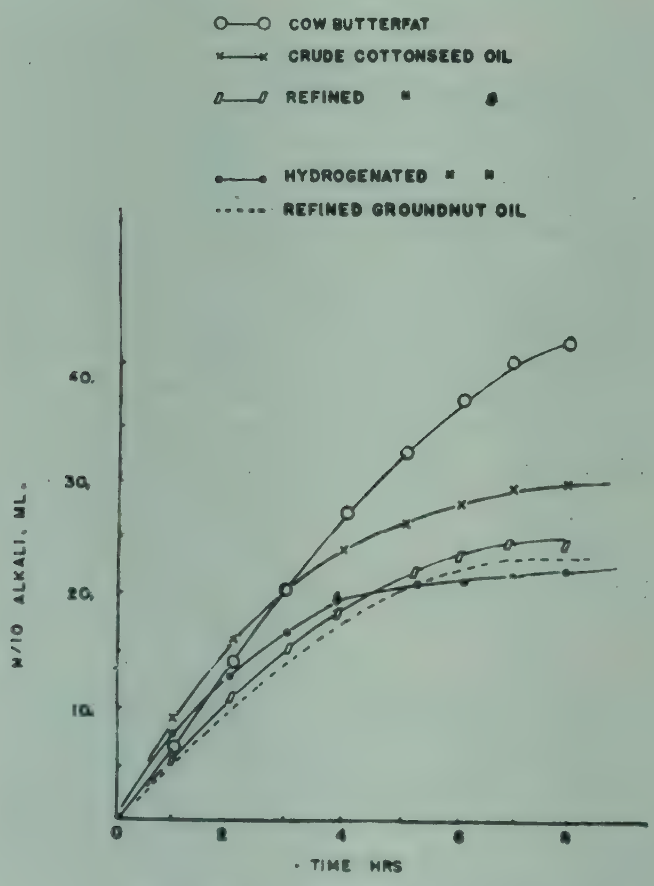

FIG. I. RATE OF LIPOLYSIS USING CASTOR LIPASE

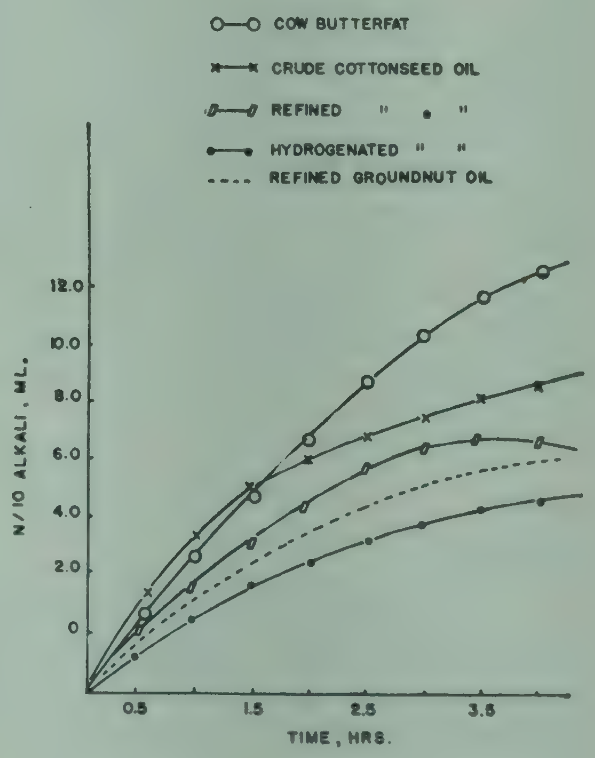

FIG. 2. RATE OF LIPOLYSIS USING PANCREATIC LIPASE

The digestibility coefficients of crude, refined and hydrogenated cottonseed oil were determined by feeding adult rats on diets containing the various fats at 10% level. The method adopted was similar to that of Narayana Rao and De.[9] The composition of the experimental diet is given in Table II. Calculation for digestibility coefficients were made in the usual manner after correction for metabolic fat. The results presented in Table III show that all the fats tested are almost completely digestible in rats.

TABLE II

Percentage Composition of Experimental Diets

Casein (extracted)	18
Salt mixture	4
Vitaminised starch	5
Sugar	10
Agar-agar	1
Corn starch	52
Fat	10

TABLE III

Digestibility of Crude, Refined and Hydrogenated Cottonseed Oil

Fat fed	Coefficient of digestibility
Crude cottonseed oil	97.5
Refined cottonseed oil	97.6
Hydrogenated cottonseed oil (m.p. 37°C.)	93.5
Cow's ghee	95.0
Refined groundnut oil	95.9

Growth–promoting Value of Crude, Refined and Hydrogenated Cottonseed Oil

Five groups of six freshly-weaned rats weighing about 40 gm. (distributed equally according to sex and litter mates) were fed for a period of 6 weeks on the experimental diets containing crude, refined and hydrogenated cottonseed oils, cow's ghee and groundnut oil. The composition of the diet is shown in Table IV. In addition to the diet each rat received two drops of Adexoline and 2 mgm. of α-tocopherol twice a week to meet their vitamin A, D, and E requirements. The feeding was carried out for a period of six weeks. The average weekly increase in weight and the increase in weight per gm. of fat intake is given in Table V. Statistical analysis of the results showed that there was no significant difference in the growth-promoting value of cottonseed oil, groundnut oil and cow's ghee.

TABLE IV

Percentage Composition of Experimental Diets

Extracted skimmed milk powder	20
Extracted food yeast	16
Chopped cane sugar	10
Vitaminized starch	5
Salt mixture (Ca- & P-free)	4
Agar-agar	1
Corn starch	35
Fat	10

TABLE V

Growth-promoting Value of Crude, Refined and Hydrogenated Cottonseed Oil

(Duration of experiment: 6 weeks)

Fat fed	Average increase in weight, g./week	Increase in weight per g. of fat intake
Crude cottonseed oil	15.35	2.31
Refined cottonseed oil	15.48	2.31
Hydrogenated cottonseed oil	14.38	2.18
Cow's ghee	15.98	2.42
Refined groundnut oil	14.40	2.41

Effect of Crude, Refined and Hydrogenated Cottonseed Oils on Calcium and Phosphorus Metabolism on Young Rats

The effect of crude, refined and hydrogenated cottonseed oils on the utilization of calcium and phosphorus in young rats was determined both by metabolism study[10] and by estimation of body calcium and phosphorus.[11] In the 3rd and 4th weeks of feeding during the growth study, the excreta were collected and by estimating the calcium and phosphorus excreted in both urine and faeces, the effect of different oils on the utilization of calcium and phosphorus was determined. The results are given in Table VI. After the feeding period of 5 weeks was over the rats were sacrificed, and from the estimated body calcium and phosphorus the effect of different oils on calcium and phosphorus utilization was determined. The results are given in Table VI. The results show that there was very little difference in the retention of calcium and phosphorus in growing rats fed on diets containing the different fats.

TABLE VI

Effect of Crude, Refined and Hydrogenated Cottonseed Oil on the Utilization of Calcium and Phosphorus in Young Rats

Fat fed	Metabolism study		Body calcium method	
	% Ca utilized	% P utilized	% Ca retained	% P retained
Crude cottonseed oil	74.7±3.1	66.7±2.5	67.5±2.4	62.6±2.1
Refined cottonseed oil	79.5±3.3	68.3±3.4	71.5±2.8	65.4±3.4
Hydrogenated cottonseed oil ...	71.1±2.8	61.0±3.0	72.4±2.6	53.4±2.6
Cow's ghee	83.2±2.9	65.4±2.6	76.8±2.7	58.4±2.9
Refined groundnut oil	76.2±2.1	59.2±3.2	66.2±2.4	54.2±2.1

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4. LABORATORY METHOD FOR EVALUATING THE QUALITY OF WASHED COTTONSEED OIL

By

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The paper describes a method which can be adopted in the laboratory for evaluating the quality of washed cottonseed oil before purchasing the same. Thus the behaviour of the oil on the plant-scale can be known in advance.

Introduction

In purchasing and processing cottonseed oil, we always felt the necessity of a laboratory method by which we could have some idea of how a particular lot of cottonseed oil would behave on the plant-scale; it had been observed that a particular lot of washed cottonseed oil may have an apparently light colour and pass our colour specifications, but still may not yield good, light-coloured oil on refining and bleaching on a large-scale, because of the fixation of colour bodies. For evaluating the refinability and bleachability of washed cottonseed oil the method described below was found to be useful.

Method

Take 300 gm. of washed cottonseed oil in a 600 ml. beaker. Add 3 ml. of caustic lye (470 gm. per litre) using a small graduated pipette. The oil which is at a temperature of 30°C is stirred at 200 r.p.m. with the help of a mechanical stirrer. Stirring is continued for 30 min. after the addition of lye. The temperature of the oil is then slowly raised to 60°C by keeping the beaker in a hot water bath. Slow stirring is done during this heating with a glass rod. The mass is then settled for 3 hours and the supernatant layer of oil is filtered through filter paper to remove traces of soap.

100 g. of the filtered oil are taken in a 250 ml. beaker. 2 g. of Tonsil ACA bleaching clay and 0.2 g. of Norit OPL New active carbon are added. The whole is heated to 90°C and maintained between 90-95°C for 30 min., stirring the mixture at 250 r.p.m. with a mechanical stirrer. It is then filtered through a filter paper and colour readings are taken.

Treatment with a strong lye gives a thick soap, which separates out easily, and the supernatant oil is clear and relatively free from moisture and soap. This avoids the water-washing and drying step of refining which are cumbersome to carry out on a laboratory -scale

DISCUSSIONS

Discussion Leader: Dr. K. S. Murti,
Oil Technological Institute,
Anantapur.

Paper 1

K. S. Murti. It is felt that even though a sufficient number of samples of many varieties have been analysed, the number of samples of certain other varieties studied are very few and statistically not significant. Therefore, the author and his colleagues would do well to complete this aspect of the work also. Further, little work has been done on the utilisation of hulls which form about 50% of the seed. As hulls are rich in pentosans, work to develop their utilization may be undertaken.

T. V. Subba Rao. What is the difference in the gossypol content of *desi* and American cottonseed?

K. S. Murti. The gossypol contents of *desi* and American cottonseed are almost the same.

Paper 2

K. S. Murti. The urea-separation technique is more suited to recovery of saturated and unsaturated acids of an oil than for determination of fatty acid composition. The method is reported to have been employed commercially in U.S.A. for resolving petroleum fractions. This technique might be extended to the removal of free fatty acids in the oil. In the case of crude cottonseed oil it may have advantages over alkali-refining because the soapstock is dark and very difficult to deal with. Marked decrease of F.F.A. in preliminary work on the refining of groundnut oil by this method has been observed in our laboratory.

G. V. Sirur. What will be the effect of denatured alcohol on the adduct formation? Can the method be used for refining of crude cottonseed oil?

H. V. Parekh. It has been found that the F.F.A. of solvent-extracted oils goes as high as 20-22 per cent. Is there any method for refining such high-acid oils?

K. T. Achaya (replying): 1. Urea has been used for de-acidification of oils by Loury in France and more recently by Mehta at Nagpur. About 10 parts of urea reduced the F.F.A. from 3.8 to about 0.2. There is no reason why the method should not work for high-acid oils.

2. Since the alcohol in the urea adduct method of separation is not a true solvent, but merely a vehicle for reducing fluidity and perhaps also a catalyst, denatured alcohol would probably work just as well as purer alcohols.

3. The urea method is not, as stated by Dr. Murti, applicable mainly to saturated fats. Indeed its virtue over other commercial methods of separation of fatty acids lies in the fact

that it will separate, to a fair extent, oleic from linoleic acid as shown by fraction D in Table II, of I.V. 166 (I.V. of pure linoleic acid 181.4).

K. S. Murti. As the method gives a certain degree of selectivity it may be useful for commercial separation of fatty acids. The economics of the process, however, has to be carefully studied.

PAPER 3

K. S. Murti. No significant difference was observed between the growth-promoting value of diets containing 10% of crude, refined and hydrogenated cottonseed oil, refined groundnut oil and cow's ghee and all were found to be digestible to the extent of 95-98% by the rat. It is suggested that the authors investigate the vitamin and pro-vitamin contents of a number of cottonseed oils produced by different methods.

M. Narayana Rao. The work reported in this paper was carried out at the desire of many vanaspati manufacturers. The composition of the fat has an effect on the utilisation of calcium by the body. Work is still required to be undertaken on the vitamin contents of various samples of cottonseed oils.

T. V. Subba Rao. We have been advocating the use of cottonseed in this symposium mostly on the ground that it should be considered as a by-product. It should be given its due importance as a main oilseed. Investigations on two aspects should be taken up in research laboratories: (1) Investigations on cottonseed proteins, especially their utilisation for fibres and adhesives, (2) α-Cellulose in linters particularly as regards degree of polymerisation.

PAPER 4

K. S. Murti. The advantages of this method seems to lie in its simplicity (no water washing and drying) and speed (about 4 hours). But the two steps suggested have to be adopted by the industry. The use of strong lye of 47% of 60°Bé lye is used. If 60°Bé caustic is used, the colour will be removed to a far greater extent than that possible in industry. The method appears similar to that given by Deacon, Harris and Wamble (J. Amer. Oil Chem. Soc., 1957, *34*, 367) except that they had applied it for refining crude oils and the present authors have used washed cottonseed oil. Perhaps this method could be made more useful by using 20° or 30°Bé alkali and centrifuging the soapstock as was done by the American workers, without resorting to settling for 3 hours.

B. S. K. Shastry. From the practical point of view the method may be split into two parts: (1) extent of refining, and (2) bleachability of the cottonseed oil. As the author's factory has facilities for large-scale processing, it would be interesting to find to what extent the method could form a ready guide to the practical results that are achieved.

S. Raghavendar Rao. It is desirable that the cottonseed industry gives some thought to the adoption of standards based on refining loss and bleachability of the oil. It is well known that in the U.S.A. cottonseed oil trading is based on "cup loss" and refined and bleach colour. Although it may not be possible for all crushers to maintain equipment for these determinations, a simpler method to evaluate the oil quality has to be worked out.

G. V. Sirur. In the U.S.A., crude oil is sold to the refiner. In India such a procedure is not done as washed oil is the basis of trade. Cottonseed crushers may adopt any test and even the ISI accept it, but consumers have the final say. So the vanaspati industry should agree to some mutually-acceptable standard.

W. J. H. Bendixsohn. The question of standardisation was discussed by the Vanaspati Manufacturers Association last year. In my opinion we should follow the example of the U.S.A. in this matter. We should evolve a standard. Every standard has its shortcomings. So I would suggest that we may tentatively adopt the American standards and then modify them later to suit Indian conditions. I must say that at present, only about 25% of the oil comes up to the standard, 15% may pass, but the remaining 60% is just no good. Small factories are hard hit due to the insecurity in the trade. As far as I know there is a Committee in the ISI for the standardisation of cottonseed oil in which vanaspati manufacturers are also represented.

G. Khandwala. It requires 4-5 hours for the bleachability test to be performed. When we receive cottonseed oil in the factory it is not possible to wait for so long. I would like to know if there is any method for bringing down the period of bleaching.

W. J. H. Bendixsohn. A short-test as desired by the previous speaker is apparently not available.

G. V. Sirur. The purchase of washed oil can be based on refining loss. It is not necessary for this purpose to have the bleachability test.

G. Khandwala. When we buy the oil we usually have to give the specifications with regard to colour and F.F.A. and the seller has to accept them before the oil is sent to the vanaspati factory. The oil will have to be analysed either in the factory or sent to an independent analyst but both the methods are likely to take time.

G. V. Sirur. We can accept a particular colour. If a good-quality oil is supplied, the consumer as well as seller would be benefited. The oil may be accepted to start with on a colour basis, and the payment can be made at a later stage based on refining and bleaching tests.

W. J. H. Bendixsohn. Commercial laboratories can conduct analysis on samples of the oil and their results could be accepted by the trade.

G. V. Sirur. Some sort of examination or inspection should be made prior to the oil being taken to the factory. I do not think any cottonseed crushers will object if a reputed firm agrees to buy on condition that the results of the testing laboratory are binding. It is just a matter of confidence in each other. Minor differences as regards colour, etc. are likely to arise and unless there is some sort of mutual confidence in each other, these cannot be solved.

J. M. Shah. As per the existing marketing conditions, 90% of the value of the oil is paid on delivery of the oil in the factory and the balance is paid after the chemical analysis is received. A few samples could be sent in advance to obtain the chemical analysis. For better-quality oil a higher payment may be made so that the supplier may get an impetus to product it.

K. S. Murti. Though the discussion is to some extent related to the subject of refining, the main point of the paper is side-tracked. If any person is ready to say anything on the merits of the method or any suggestion for altering, it, he is welcome to do so.

M. A. Sampathkumaran. I suggest the adoption of centrifugal separation of the oil.

K. S. Murti. In this paper, Shri Das has made it clear that the object of this method is that the washed oil could be tested and purchased. The method has been suggested for finding out whether a particular lot of oil is properly bleachable or not. For making the method still more rapid the centrifuge may be used which will reduce the time to 2 to 2.5 hours.

In regard to whether the existing standards for washed oil should include a bleachability test, personally I think it is desirable. Not only this, but many other items also may have to be included in the existing standards for washed cottonseed oil. For example, the present limit of iodine value is too high. It is desirable that this method may be tried and a large amount of data obtained, and then if it is considered necessary, let us suggest it to the I.S.I.

F. G. T. Menezes. The question of including bleachability as one of the standards for purchase of cottonseed oil has been examined at some length by the cottonseed oil *ad hoc* enquiry committee consisting of representatives of Government, the vanaspati industry and crushers. It was decided that it would be useful to include the bleachability test as one of the standards, and a recommendation is going from that committee to the I.S.I. to re-examine the present standards for cottonseed oil.

G. Khandwala. Whenever fresh oil arrives, we have to dump it in a tank which already contains cottonseed oil. We want to find out the bleachability of the fresh oil before it is put into the common tank.

K. S. Murti. The first sample of the oil on which the contract will be made must be sufficient and the bleachability test will have to be made on it. Then the second question will be whether the bulk rececived will actually conform to the sample; if it does not, naturally the supplier will have to bear the cost.

So far as the method is concerned, in my opinion as a starting point it is a good method. But, as I have already suggested, I do not favour such a strong lye as 50 or 47 per cent being used for refining, because the colour will be entirely different from the colour of the oil obtained from the normal processing method. For shortening the time the centrifuge may be used. In any case it is a good method but requires modification before it is taken as one of the items in the standard.

SECTION VIII

GENERAL CONSIDERATIONS

Discussion Leader: Dr. S. A. Saletore,
Regional Research Laboratory,
Hyderabad.

1. PROCESSING OF COTTONSEED AND COTTONSEED OIL–A REVIEW

PART I: WORLD TRENDS IN PRODUCTION OF AND TRADE IN COTTONSEED AND COTTONSEED OIL AND THE SCOPE FOR DEVELOPMENT OF INDIAN COTTONSEED OIL INDUSTRY.

By

T. V. SUBBA RAO

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The present situation of cottonseed and cottonseed oil vis-a-vis the technological developments and changes in the production-consumption pattern of other oils is discussed. Trends in world production, consumption and export of the major oilseeds are analysed.

An increase in cottonseed oil production in India would be a welcome addition to the total pool of edible oils and would be in the interest of the country's economy.

Introduction

The development programme for vegetable oils and related industries in India is of great importance and interest not only to India, but also to all the principal oils and fats producing and consuming countries in the world because of the important place this country holds in world production of and trade in vegetable oilseeds and oils. This calls for a consideration of the economic and technological aspects of this development programme in the context of the economic changes within the country and the international trends in production and consumption of and trade in oilseeds and oil-bearing materials.

In particular, a study of the inter-relationship between changing economic situations and technological advances country-wise and commodity-wise appears desirable. Studies of this nature could be expected to throw light on the probable opportunities for future development and provide an objective basis for an analytical approach to future economic and technological developments in the light of past and present trends. This approach would be of particular interest to the research worker and the planner to visualise long-range problems of industrial importance. This paper is mainly restricted to a study of the general production and trade trends in cottonseed and cottonseed oil. Other economic and technological aspects will be dealt with in subsequent communications on this subject.

The present economic situation and state of technological development in oils and related industries is the outcome of the mutual interaction of the two in the important countries which individually and collectively influenced the world trends. In some instances, changed economic situations had necessitated technological developments by stimulating research. In yet others, technological advancements had changed the economic importance of individual oils and fats. In consequence of these interactions in the major producing and consuming countries, the supply-demand position in the international markets and the economic values for individual oils and fats has been fluctuating.

We have, in India, a potential for production of over 1,50,000 tons of cottonseed oil, and we are endeavouring to implement a phased programme of development of this entire resource. In addition, we are also trying to develop and exploit more fully our vast potential of other fatty resources through several short-range and long-range programmes, including the rapid expansion of the solvent-extraction industry. These activities are designed to meet the increasing internal demand for oils and fats and to leave a sufficient surplus for our export trade. They could possibly lead to a changed pattern in the production and consumption of vegetable oils. Similar development programmes are being implemented in other countries too, but each is distinctive in both internal and external situations.

In this effort of racing to achieve the goal, with different initial starts and different speeds, where would we be in years hence compared to the other countries? How best can we channel our internal economy and how phase our research activities, both within the industries and at University or Government Technological Laboratories? These aspects in relation to cottonseed and its by-products naturally engage our attention. Based on published information, an attempt is made in this paper to analyse the present situation of cottonseed and cottonseed oil and the trends during the last two decades. The original data were worked out further and included in the form of percentages or index; they are presented either in tabular form or as charts and curves. Despite much condensing, the data still remain bulky, but are considered necessary for a discussion of the several aspects treated in this part and those to be subsequently evaluated.

World Trends in Production and Export of Oils and Fats

World production of oils and fats has increased 135.3% from the pre-war (1934-38 average) level of 21.587 million metric tons to 29.210 million metric tons (forecast) in 1957 (Table I). During these 23 years, the share of vegetable oils and fats increased from 55.6% of the total for all oils and fats in pre-war years to 60.8% in 1957. Concurrently, the share of animal oils decreased from 40.6% to 36.4%, and that of marine oils decreased from 3.9% to 2.8%, the vegetable oils and fats thus gaining in economic and industrial importance.

Amongst the marine oils, production of whale oil was on the decline and that of fish oils registered slight improvement. Amongst the animal fats, production of butterfat and ghee was on the decline; increase in production was seen both for lard and for tallow, particularly the latter. However, the production appears to be levelling off during the last few years. There was a big jump between the pre-war years and 1954 in consequence of technological developments in the rendering of tallow and creation of new industrial outlets for inedible tallow through fat splitting and fatty acid distillation. The rapid rate of development of the synthetic detergent industry in the West has also contributed. Further, lard has gained importance in the shortening industry.

Vegetable oils and fats can be classified into 'edible type', 'edible-industrial type' or 'palm oils', 'industrial type', and 'minor oils and fats ' (Table II). The production of all vegetable oils and fats increased from 12.0 million metric tons in pre-war years to 17.74 in 1957, an increase to 147.8%. Leaving aside minor oils, the share of edible-type oils increased from 30% to 36% of all oils and fats and from 54% to 60% of the vegetable oils for these two years of comparison. The production, in terms of tonnage, increased 162%, from 6.5 to 10.6 million metric tons.

Both palm oils and industrial oils have increased in production from 2.7 to 3.7 million tons (138%) and from 2.6 to 3.2 million tons (124%) respectively. But the increase in production in these two types was much less than that shown by edible oils. The slow rate of increase in palm oils has led to the rapid growth of the syndets industry to some extent. Similarly, the slow rate of increase in production of industrial oils in general and of linseed oil in particular has paved the way for the advent of synthetic resin-based surface coatings of the oil-modified types. Dehydrated castor oil has gained a new economic status, and through recent new techniques for upgrading of linoleic-rich oils, some 'edible-type oils' like soyabean have attained a permanent place of no small importance in the coatings industry.

The cause for the unequal rate of increase in production between the above three major types of vegetable oils and fats can be deduced by re-classifying them according to source (Table III). The largest increase is in oils derived from annual agricultural crops, like groundnut, soyabean, sunflower sesame, linseed, castor, rapeseed, and teaseed in China. Both agricultural by-product oilseed crops (mainly cottonseed oil, and corn oil to a small extent) and plantation crops show only a modest increase in production. This differential rate of increase is a consequence of the limited scope for increase in acreage in cotton and plantation crops, while in agricultural primary oilseed crops increase in acreage is permissible to some extent since oilseeds are a primary economic commodity. In addition, plantation crops are restricted to localised regions, and thus the scope for a substantial increase in production is limited, while development programmes can give only long-range results.

Amongst the edible type of oils, production of groundnut oil appears to be levelling off in recent years, while the new entrants soyabean and sunflower have been increasing at galloping speed. There has been no important change in the production index of sesame and olive oils. Cottonseed oil production has increased to 126% at 1.8 million metric tons during these two decades, but it has been almost steady at 1.8 to 1.9 million tons during the period 1954-57 (Table I).

A study of the trends in production of all oils and fats country-wise indicates that the increase in production in India during these two decades was only to 113% as against 127% for the whole world (excluding U.S.S.R.). Amongst the Asian countries, the Philippines, Malaya and Turkey are having a much faster rate of increase. Amongst other countries, Canada, the U.S.A., Brazil, Nigeria, Belgian Congo, the Union of South Africa and Western Europe countries registered a much higher increase in production than India (Table IV).

The world exports of all oils and fats during these two decades increased to 127%, almost the same level as the increase in production of oils and fats. (Table VI). The increase in exports was highest for animal fats (176%), against 121% for vegetable oils and fats and 101% for marine oils. Tallow has been dominating the field of animal fats.

Amongst the vegetable oils and fats, exports of palm kernel oil, groundnut oil, and linseed oil have shown no significant increase during these two decades. Coconut oil and palm oil have shown some increase, but the latter seems to be levelling off at a 550,000 metric tons level. Soyabean oil has registered an appreciable increase.

Cottonseed oil exports increased from 189,000 tons in pre-war years to 378,000 tons during 1955 and 1956. During 1957, it has declined to 313,000 tons (forecast), which suggests that the world markets could absorb another 65,000 tons if available. (Table V). There has been a decline in the exports of all oils from India (and Ceylon) during recent years (Table VII).

Reverting to Table I, the annual rate of increase in world production of all oils and fats during the last 21 years is 1.67%. Assuming the world population increases annually by 1.5%, the *per capita* annual consumption of oils and fats (vegetable, animal and marine) for both edible and non-edible uses has increased from 22.8 lbs. in pre-war years (2.084 billion population assumed) to 23.5 lbs. in 1957 (2.74 billion population). The rate of increase in production of oils and fats has thus been sufficient not only to provide for the increasing population but also to permit a small overall increase in the *per capita* production and consumption.

Although this progress would appear not unsatisfactory, nutritional standards require a minimum consumption of 45 lbs. *per capita* per annum. The demand for non-edible uses of oils is steadily increasing and during the past few years, they have started entering a new phase of activity as chemical raw materials, competitive to coal and petroleum, in the synthetic polymer and other chemical industries. These trends have caused an imbalance in the supply-demand position of 'edible' *versus* 'non-edible' uses for oils and fats.

The different levels of industrialisation and living standards in the major oil and fat-producing countries, varying rates of population growth and the aspirations of the under-developed countries to improve, have all contributed to this imbalance in the consumption and trade pattern, both local and worldwide, of oils and fats.

The impact of these economic changes has resulted in greater emphasis on techniques for upgrading non-edible oils and fats into edible ones; in an interchange of the edible oils amongst themselves for edible uses; and in a relative gain in importance of oils like soya-bean, cottonseed and sunflower. Alongside, the reverse process of the use of these three edible oils in particular for non-edible uses (in the surface coatings industry) is gaining importance. The net result is that the conventional distinction between 'edible type' and 'non-edible type' of oils and fats can no longer be rigid, either for individual oils or for groups. The deciding factor is the economic situation and the level of technological advancement in any geographic region.

So far we have considered the production and exports of oils and fats. We might consider the production and exports of oilseeds which are the primary products and which give an idea of the potential for production of vegetable oils and fats. The data in Tables VIII to XVII are based on the information published in "Vegetable oils and oilseeds—A review", 1954 and 1958 editions,[1,2] rearranged and further analysed for this purpose. The charts and the trend curves were also based on these official statistics.

During the period 1939 to 1957, the production tonnage of all oilseeds increased, although to different extents. As oil is the main product of economic value, it is more convenient to study the relative economic importance of individual oils and fats by referring to the oilseeds in terms of their oil equivalent, using as conversion factors the world average yields of oils in commercial crushing of oilseeds, as given in Table VIII. This assumes that all the oilseed produced is crushed. However, the production figures represented in terms of

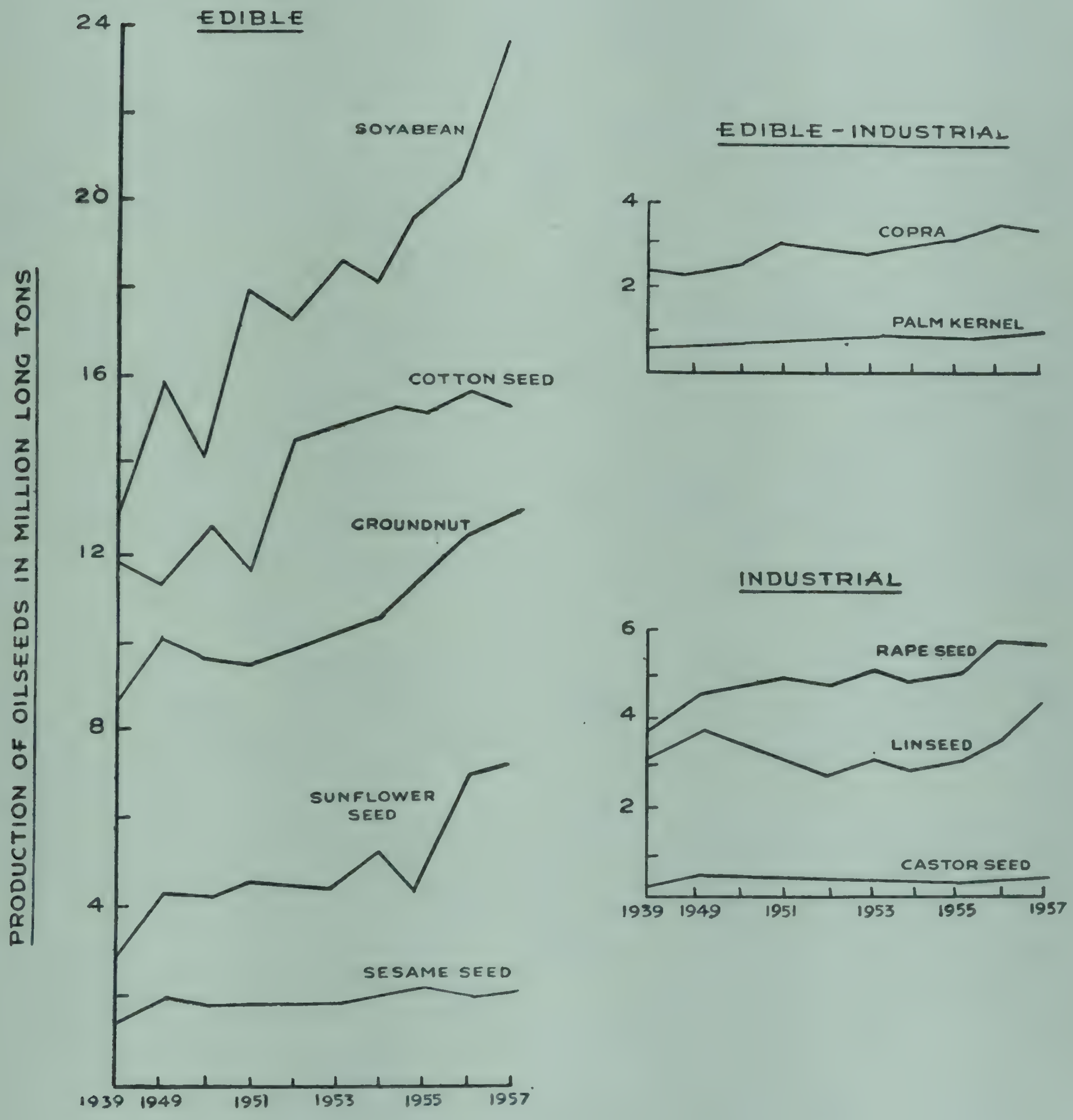

Fig. 1:— World Production of Major Oilseeds

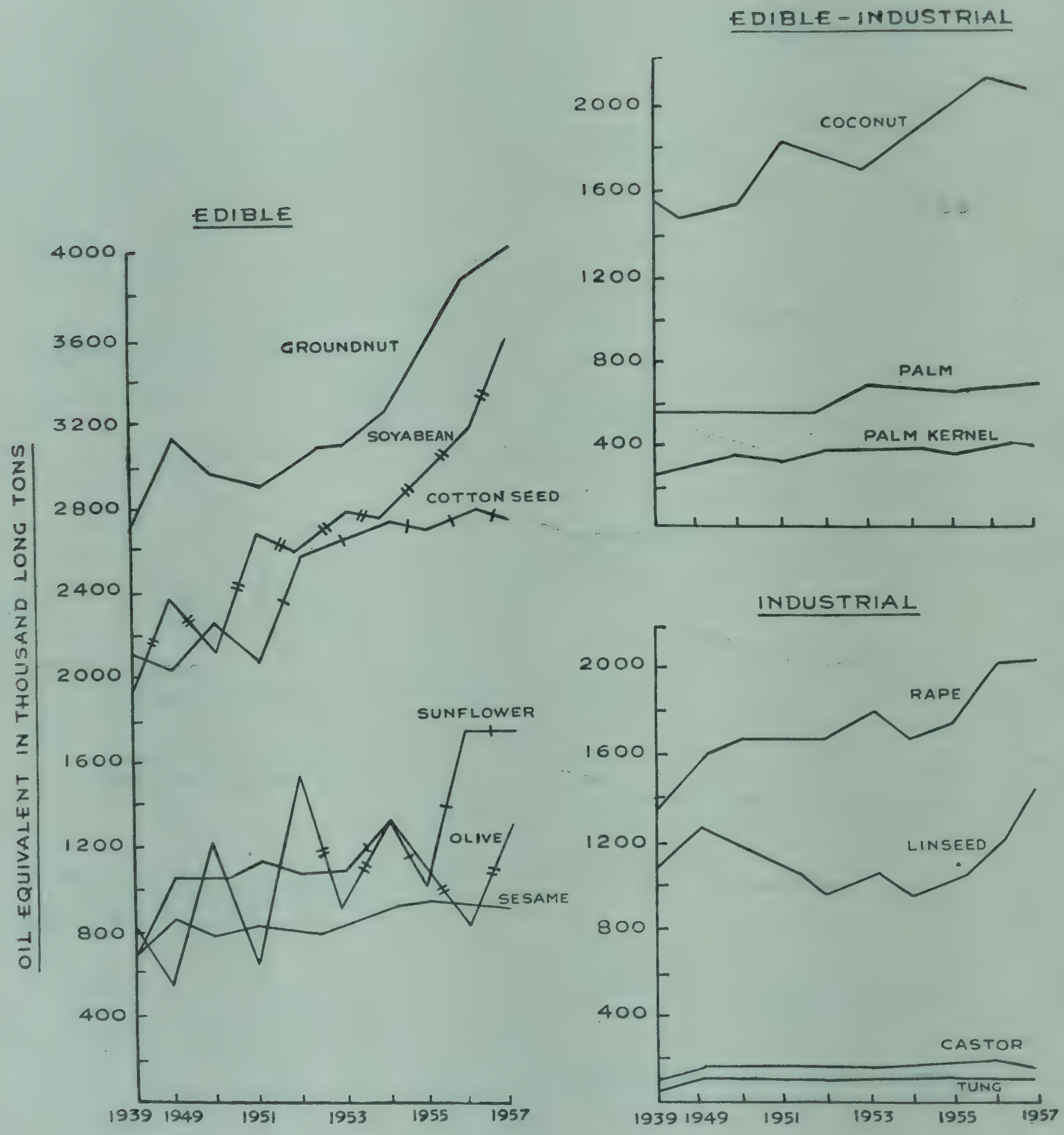

Fig. 2:— World Production of Major Oilseeds (as Oil Equivalent)

oil equivalent do not represent the actual production as oil, as only part of the seed produced would be used for expression or extraction of oil from the seed, the rest being used as such for cattle feeding, seeding, etc. The proportion of seed actually used for crushing varies for the individual oilseeds and also countrywise. For estimation purposes, it is reckoned that the percentage of the world crops retained for seed and utilised for purposes other than for production of oils and fats is as follows: groundnut 35 to 45, soyabean 30 to 35, cottonseed 25, sesame 15 to 25, sunflower 15, rapeseed and linseed 10, and castor 5.

It should also be noted that the yield of oil or fat from a ton of seed varies according to the initial oil content, and the efficiency of the mechanical expression or solvent-extraction technique used. As these factors vary for the various oilseeds produced in the same or different countries, it would be safer to use the world average[2] to get a comparative overall picture.

The production of oilseeds in oil equivalent represents the quantity of oil obtainable on world average yields (as shown in Table VIII) from the entire oilseed crop. This increased from 13.8 million long tons in 1938-39 to 18.1 million long tons in 1951-52 to 1955-56 (quinquennial average) and to 21.0 million long tons in 1956-1957, with a corresponding increase in the index to 132 and to 153 respectively (Tables VIII & IX). The rate of increase for all vegetable oils and fats has been high during the last 6 or 7 years. Edible type oils had the highest rate of increase with 160 index, as against 131 for the edible-industrial type and 127 for the industrial type. It may be deduced that the demand position has called for a faster rate of increase in the production of edible type oilseeds. This is to be expected from the rate of increase in population and the urge for improvement in nutritional requirements.

The share of the individual oilseeds (in oil equivalent) in the total world production of oilseeds and vegetable oils (in oil equivalent), averaged for the period 1951-52 to 1955-56, (Table VIII) reveals that edible oilseeds and oils account for 66.8% at an estimated 18.1 million long tons (in oil equivalent), the rest being shared by edible-industrial (16.0%) and industrial (17.2%) types.

The yearly fluctuations in production of oilseeds for the nine years beginning 1948-49 (1949) compared to 1938-39 (1938) are shown in Fig. 1. The new emphasis on soyabean and sunflower seeds, reflected in a rapid increase in production of seed, is easily seen from the curves. The rate of increase in production of groundnuts has been relatively slow during the past few years compared to that during the decade 1938-1948. Production of cottonseed has been on the increase, but shows tendencies of levelling off. Somewhat similar tendencies are noticeable in the case of the other oilseeds (Fig. 1).

The yield of oil per ton of seed is lower for soyabeans, cottonseed, and sunflower than for other oilseeds. The relative importance of the world oilseeds crops can be seen from the curves in Fig. 2. Despite the higher tonnage production of soyabean and cottonseed, they fall below groundnut in terms of oil equivalent. It may be noted that during these two decades, soyabean scored over cottonseed and is still increasing.

The production trends (in terms of oil equivalent) for oilseeds and oils for the three main groups and for the world total of all groups are shown in Fig. 3. It can be seen that the world total is influenced more by the trends in the edible oil type than by those in the other two types. It is to be inferred that any effort for increased production of the edible

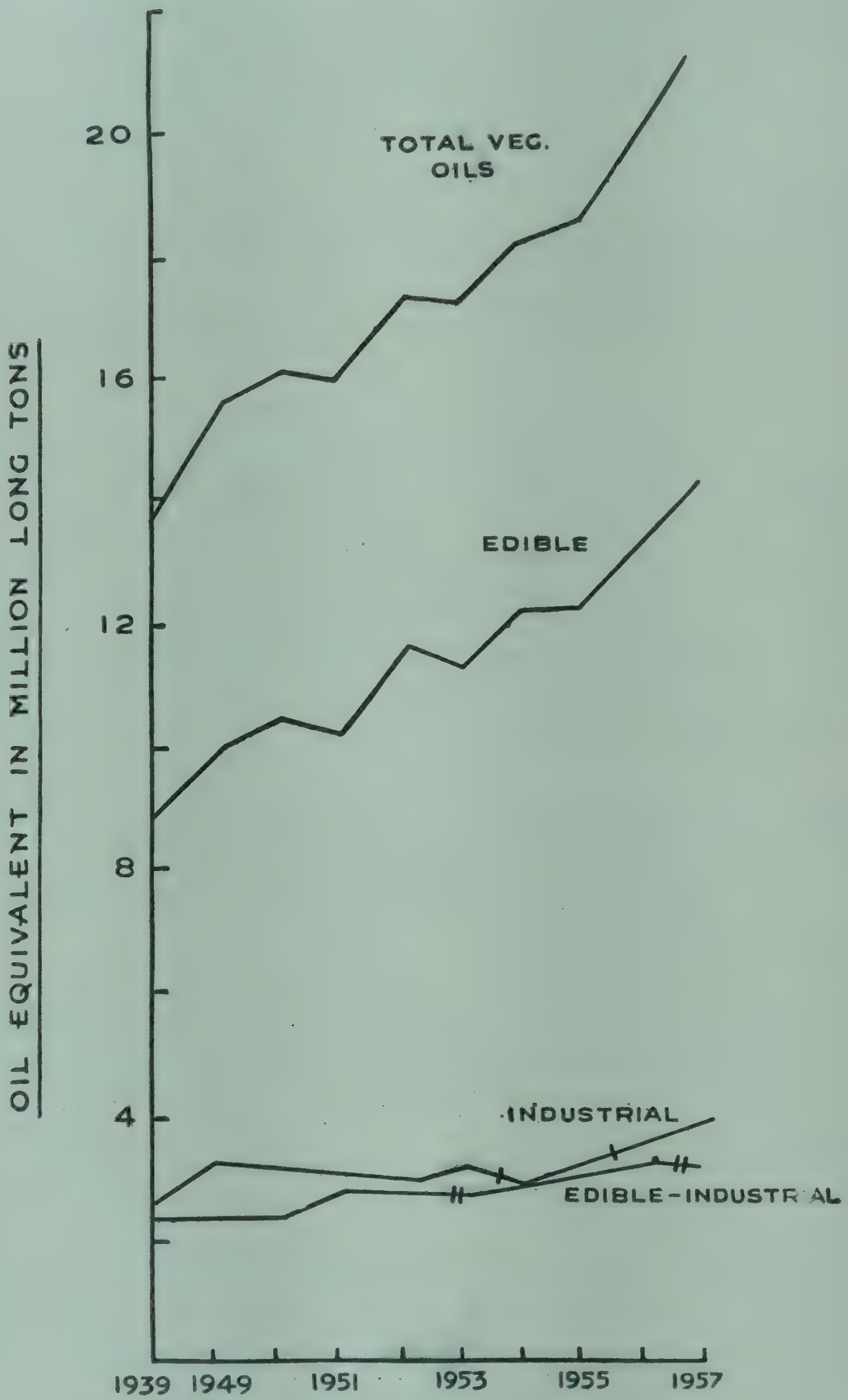

Fig. 3:— World Production of Major Oilseeds (as Oil Equivalent), shown classwise

type of oils would be of more immediate interest to the world markets. From this angle, our efforts to develop the cottonseed oil industry should be welcome.

Among the edible type oils, sesame and olive which are almost steady in their share of the total production of oilseeds and oils (in oil equivalent) during the past two decades (Table VIII); the share of soyabean and sunflower steadily increased while that of groundnut and cottonseed decreased. The increase in the share of the former two, besides compensating for the decrease in the share of the latter two, has resulted in a net increase in the share of the edible type of oilseeds from 63.8% to 67.1% during these two decades, while for the other two types—edible-industrial and industrial—there has been a decrease from 17.3% to 14.9% and from 18.9 to 18.0% respectively.

The trend curve for edible oilseeds and oils (in terms of oil equivalent) in Fig. 3 indicates that in the coming years an annual increase in production of edible oilseeds and oils to the extent of nearly 900,000 tons (in oil equivalent) might be necessary to meet the world demands. This increase has to be met mostly from amongst the four—groundnut, cottonseed, soyabean, and sunflower—either through increase in acreage, increased yield of seeds per acre, increased yield of oil during crushing obtained by adopting more efficient methods of expression or extraction, or through a combination of these. From the trends it would appear that the chances for substantial increases in production of groundnut and cottonseed would be less than for soyabean or sunflower due to limitations in increasing the acreage.

India can contribute towards increased production of these oils, and to world supplies, by increasing the yield of seed per acre and by expanding solvent extraction for recovery of residual oil in cake.

World Net Exports of Oilseeds and Oils

The oil available in the seed is shared between the human, animal and plant populations. This sharing varies from country to country, and also commodity-wise. Besides, some 5-10% of the seed crop, would be required for seeding purposes. It is difficult to make a good estimate country-wise of the actual consumption in the form of seed and oil separately, for want of detailed information on the changes in the crushing industry country-wise and commodity-wise. A guess can be made by considering together the production trends and the net exports trends of the principal producing countries.

The net exports of individual oilseeds and oils (in total oil equivalent) show that for 1956 groundnut is still below the pre-war level at 83 index, the lowest for all oilseeds and oils both in the edible and in other groups, while cottonseed for the same year is high at 216 index, (Table X). From Table IX, it will be seen that the production index for cottonseed was lowest at 129.5 compared to 150.6 for groundnut, and 131 to 252 for all the other commodities except palm oil and tung oil. This shows that in spite of the higher rate of increase in world production of groundnut compared to cottonseed, the domestic demands in the producing countries have been increasing rapidly, resulting in release of a lesser proportion of the oilseed produced for export markets in the form of seed or oil. In contrast to the increasing demand for groundnut (as seed or as oil) in the producing countries themselves, the demand for cottonseed and cottonseed oil (reckoned in terms of oil) in the export markets is increasing and the main countries producing this commodity have been releasing a greater proportion of the oilseed and oil (as oil equivalent) for export markets. Table XI gives an idea of the relative position of groundnut and cottonseed.

From Table XI, it will be seen that consumption as per cent of production has not changed appreciably during the past two decades for soyabean, sunflower, *sesame,* and olive oils. The two commodities in which the change is conspicuous are groundnut, which increased in consumption from 64% to 80%, and cottonseed, which concurrently decreased in consumption from 92% to 69%, in the producing countries. One way to interpret this data is that the major portion of the rapid increase in production of soyabean, sunflower and *sesame,* and to some extent of groundnut, is for domestic markets in the principal producing countries. In the export markets, groundnut in the form of seed or oil would be easily absorbed, but all the same, cottonseed oil would also be welcome, as the main importing countries have been trying to accommodate themselves with the alternative use of cottonseed oil for edible purposes. Our interest in promoting a faster rate of consumption of cottonseed oil in our vanaspati and other industries to facilitate the export of corresponding quantities of groundnut oil would be a welcome move in the international markets in this light. It would also appear that there should be no difficulty in finding export markets for cottonseed oil even to the tune of 1,50,000 tons annually, if for any reason that approach were to be found more economical in the national interest.

The general trend in the export markets is the diminishing exports of seeds and the preferred exports of oils. This trend is most significant with cottonseed as 82% of the total exports (as oil equivalent) were as oil in 1956, as against 23% of the total exports in 1938 (Table X).

Among the different oilseeds and oils, cottonseed (in terms of oil equivalent of seed and oil) again registers a significant increase in total world net exports of oilseeds and oils (in oil equivalent). In 1938, out of the total world exports of 4.344 million long tons of all oilseeds and vegetable oils and fats (oil equivalent of seed plus oil), the share of edible type was 38.2% and the contribution of cottonseed was 3.9%. In 1956, when the world total net exports increased to 4.849 million long tons (111.6 index), the share of edible type increased to 42.1%, and the contribution of cottonseed was 7.6%. Soyabean was the only other commodity that showed a substantial increase, the corresponding figures for 1938 to 1956 being 8.8% and 14.4% respectively.

Interchangeability of Cottonseed Oil With other Edible Oils

Another important general trend in these edible type of oils is the interchangeability in their edible applications. The two major edible industrial uses of cottonseed oil in other countries are in the production of margarine and in the production of compound cooking fat.

Margarine. World production of margarine increased from 1.356 million long tons in 1938 (index 100) to 1.496 million long tons in 1948 (index 110.4) and reached a record level of 3.186 million long tons in 1956 (index 235.0). The U.S.A. was the leading producer of margarine till 1953, but since then West Germany took the role of the major world producer, accounting for 27% of the 1956 world production as against 20% for the U.S.A. The share of the other important countries in the total world production in 1956 as percentages was: Soviet Union 12, U.K. 11, Netherlands 8, Eastern Germany 6, Belgium, Denmark, France, Norway and Sweden around 3 each, Canada and Japan 2 each, Australia, Austria, Finland, and Poland 1 each, and South Africa, British Caribbean and Israel less than 1 each.

In the U.S.A., out of the total of 140,000 long tons of oils and fats used in 1938 for production of 172,000 tons of margarine, 64,000 tons was cottonseed oil (46% of all oils and fats used). Consequent to the rapid expansion in domestic production of soyabean oil, the share of cottonseed oil in the total of 495,000 tons of all oils and fats used in 1956 for the production of 611,000 tons of margarine, was reduced to 25% (125,000 tons), soyabean oil accounting for 67% (335,000 tons). Due to the cheaper prices of lard compared to vegetable oils, lard also is gaining importance in the U.S.A. for this use in recent years.

In the U.K., cottonseed oil was employed to the extent of 9% of all oils and fats used in the production of margarine in 1938, but in the post-war years the use of cottonseed oil came down to as low as 1% due to reduction in supplies. During 1954, the (peak) consumption of cottonseed oil for this purpose was 19,000 tons, representing about 6% of total all oils and fats in that year. It fell down to 11,000 tons in 1955 (3.7%) and to 9,000 tons in 1956 (3%). Hard oils (palm oils) are being used in increasing proportions during recent years.

In Canada, cottonseed oil represents only 1 to 2% of all oils used for production of margarine, soyabean oil and marine oils being the major oils. In the Netherlands, cottonseed was used to the extent of 23,000 tons in 1954 (12% of all oils and fats), but in 1956 the consumption of cottonseed oil came down to 7,000 tons (3.5%) consequent on the increased availability of soyabean oil. Small quantities of cottonseed oil are occasionally used in Denmark and Sweden.

In the margarine-producing countries in Western Europe, the general trend is to use hard oils of the palm group (coconut oil, palm kernel oil and palm oil) which are more easily available in the export markets. If increased supplies of cottonseed oil were to become available, there is a chance of its being used in higher proportions in the production of margarine.

Compound cooking fat. The four leading countries in the production of compound cooking fat in 1956 were the U.S.A. (822,000 long tons), the U.K. (145,000 tons), Canada (70,000 tons), and Western Germany (53,000 tons). In the U.S.A., cottonseed was employed to the extent of 67% of all oils and fats for this use in 1938, soyabean accounting for only 9%. In 1956, the proportion of cottonseed oil came down to 17% of all oils and fats and the share of soyabean oil increased to 42%. In the U.K., during these two years, the share of cottonseed oil came down from 37 to 4% with a concurrent increase in the proportion of palm oil from 7 to 25%. In Canada, about 5,000 to 11,000 tons of cottonseed oil were being used for production of compound cooking fat during these two decades, the share of cottonseed oil in the total of 495,000 tons of all oils and fats used in 1956 for the production of compound cooking fat fluctuating from 7 to 20%. The general trend in all these countries is to use larger quantities of cheaper lard whenever cottonseed oil becomes scarce. In the U.S.A., the relative use of cottonseed and soyabean oil is dictated largely by economics.

Conclusions

Summing up from these trends of production, consumption, and exports of the edible type of oilseeds and oils, it would appear that an increased production of cottonseed oil to the extent of about 150,000 tons per annum would be a welcome additional source of edible oils to the world pool. It can be used within India to release groundnut oil for export, or alternatively some portion could be diverted to world markets where it is likely to continue to have an important place as an edible oil. Hence the early development of the Indian cottonseed oil industry would not only be in the interests of India, but also in the interests of the world at large.

TABLE I

Estimated World Production of Individual Oils and Fats

(In terms of oil or fat)

		Pre-war	1954	1955	1956 Preliminary	1957 forecast	Individual oils as per cent of total oils and fats		Index of production in 1957 (Pre-war =100)
		(Thousand metric tons)					Pre-war	1957	
I. VEGETABLE OILS									
a. *'Edible' type oils*									
1. Groundnut	(A)	1,755	2,015	2,003	2,231	2,285	8.13	7.82	130.2
2. Cottonseed	(B)	1,453	1,871	1,854	1,898	1,830	6.73	6.27	126.0
3. Soyabean	(A)	1,263	2,180	2,416	2,756	3,050	5.85	10.44	241.5
4. Sunflower	(A)	435	814	993	1,597	1,705	2.02	5.84	391.8
5. Sesame	(A)	563	528	558	532	525	2.61	1.80	93.3
6. Olive	(C)	950	1,275	1,088	768	1,030	4.40	3.53	108.4
7. Maize	(B)	70	120	140	128	130	0.32	0.45	185.7
8. Teaseed	(A)	25	15	15	15	15	0.11	0.05	60.0
b. *Palm oils*									
1. Coconut	(C)	1,633	1,923	1,986	2,129	2,160	7.57	7.40	132.0
2. Palm kernel	(C)	355	422	418	448	445	1.64	1.52	125.4
3. Palm	(C)	644	1,006	995	1,014	1,010	2.98	3.46	156.8
4. Babassu kernel	(C)	27	35	47	43	40	0.13	0.14	148.1
c. *Industrial type oils*									
1. Linseed	(A)	1,040	1,066	930	1,038	1,240	4.82	4.25	119.2
2. Castor	(A)	178	193	218	242	245	0.82	0.84	137.7
3. Rapeseed	(A)	1,273	1,485	1,707	1,585	1,640	5.90	5.61	128.8
4. Oiticica	(C)	9	6	9	8	10	0.04	0.03	111.1
5. Tung	(C)	121	111	96	100	105	0.56	0.36	86.8
d. *All other vegetable oils* *	(D)	211	287	225	274	270	0.98	0.92	127.9
II. ANIMAL FATS									
1. Butter (fat content) and ghee (per cent)		4,160	3,928	3,730	3,818	3,840	19.28	13.14	92.3
2. Lard		2,913	3,165	3,669	3,838	3,805	13.50	13.03	130.6
3. Tallow		1,679	2,600	2,872	3,049	3,000	7.78	10.27	178.6
III. MARINE OILS									
1. Whale (including sperm oil)		507	485	470	477	465	2.35	1.59	91.7
2. Fish		323	333	395	381	365	1.50	1.25	113.0
Estimated World Total:		21,587	25,863	26,834	28,370	29,210	100.00	100.00	135.3

Notes:—The above estimates are based on detailed consideration of production in each country, using actual visible oil production where it is possible to obtain a reasonably firm estimate, *e.g.*, Europe, U.S.A., Australia. For other areas visible oil production has been calculated from crop estimates (after allowance for seeding etc)., export supplies plus arbitrary allowances for domestic consumption, livestock statistics and other relevant information.

* Includes mowrah, niger, hempseed, perilla seed and other minor oils.

Source:—Estimates by J.C.A. Faure of Unilevers given in his addresses published in technical literature, abstracted in Vanaspati Manufacturers Association (India) Circulars.

TABLE II

Estimated World Production of Oils and Fats Classified According to Source and Use

(In terms of oils and fats)

	Pre-war	1954	1955	1956	1957	Individual groups as per cent of total oils and fats		Index of production 1957 (Pre-war =100)	Individual groups as per cent of total vegetable oils and fats	
	(Metric tons '000)					Pre-war	1957		Pre-war	1957
I. VEGETABLE OILS										
a. 'Edible' oils	6,514	8,818	9,067	9,925	10,570	30.17	36.20	162.3	54.26	59.60
b. 'Palm' oils	9,659	3,386	3,446	3,634	3,655	12.32	12.52	137.5	22.15	20.61
c. 'Industrial' type oils	2,621	2,861	2,960	2,973	3,240	12·14	11.09	123.6	21.83	18.27
d. All other vegetable oils	211	287	225	274	270	0.98	0.92	127.9	1.76	1.52
Total ...	12,005	15,352	15,698	16,806	17,735	55.61	60.75	147.8	100.00	100.00
II. ANIMAL FATS	8,752	9,693	10,271	10,706	10,645	40.56	36.44	121.6		
III. MARINE OILS	830	818	865	858	830	3.85	2.84	100.0		
Estimated World Total	21,587	25,863	26,834	28,370	29,210	100.02	100.03	135.3		

TABLE III

Estimated World Production of Oils and Fats Classified According to Source

(In terms of oils and fats)

	Pre-war	1954	1955	1956	1957	Individual groups as per cent of total oils and fats		Index of production 1957 (Pre-war =100)	Individual groups as per cent of total vegetable oils and fats	
	(Metric tons '000)					Pre-war	1957		Pre-war	1957
I. VEGETABLE OILS										
a. Agricultural oilseed crop sources	6,532	8,296	8,840	9,996	20,705	30.26	36.65	163.9	54.41	60.36
b. Agricultural by-product oilseed crops sources	1,523	1,991	1,994	2,026	1,960	7.06	6.71	128.7	12.69	11.05
c. 'Plantation crop' sources	3,739	4,778	4,639	4,510	4,800	17.33	16.44	128.3	31.14	27.06
d. All other minor vegetable oils	211	287	225	274	270	0.98	0.92	127.9	1.76	1.52
Estimated World Total	12,005	15,352	15,698	16,606	17,735	55.61	60.75	147.8	100.00	100.00

TABLE IV

Estimated World Production (Excluding the U.S.S.R.) of Fats and Oils by Continents and Major Producing Countries, Pre-war Average, 1948 and 1955

Continent & Country	Pre-war Average 1934-38	1948	1955[a]	Production as per cent of world total		Production Index for 1955 (Pre-war average =100)
	(Thousand metric tons)			Average 1934-38	1955	
a. *North and Central America*						
1. United States	3,018	4,595	6,180	15.81	25.37	204.8
2. Canada	190	352	400	0.99	1.65	210.5
3. Central America	200	250	370	1.05	1.49	185.0
Total ...	3,410	5,200	6,950	17.9	28.6	203.8
b. *South America*						
1. Argentina	740	774	500	3.88	2.03	67.6
2. Brazil	380	442	471	1.99	1.94	124.0
3. Other countries	200	240	320	1.05	1.32	160.1
Total ...	1,320	1,450	1,290	6.9	5.3	97.7
c. *Asia*						
1. India	1,950	1,980	2,190	10.23	9.01	112.6
2. China	3,270	3,130	3,270	17.12	13.46	100.0
3. Philippines	405	567	633	2.12	2.61	156.3
4. Indonesia	690	473	690	3.61	2.84	100.0
5. Malaya	155	120	158	0.82	0.65	102.0
6. Pakistan	223	253	300	1.17	1.23	137.7
7. Ceylon	135	144	154	0.71	0.63	114.1
8. Japan	147	31	145	0.77	0.60	98.7
9. Turkey	170	250	280	0.89	1.15	164.7
10. Other countries	330	210	330	1.73	1.36	100.0
Total ...	7,470	7,160	8,140	39.1	33.5	109.0

TABLE IV—*(Contd.)*

Estimated World Production (Excluding the U.S.S.R.) of Fats and Oils by Continents and Major Producing Countries, Pre-war Average, 1948 and 1955

Continent & Country	Pre-war Average 1934-38	1948	1955[a]	Production as per cent of world total: Average 1934-38	Production as per cent of world total: 1955	Production Index for 1955 (Pre-war average =100)
	(Thousand metric tons)					
d. *Africa*						
1. Nigeria	553	627	804	2.89	3.31	145.4
2. Fr. West Africa	340	281	282	1.78	1.16	82.9
3. Belgian Congo	180	252	317	0.94	1.31	176.1
4. Union of South Africa ...	27	71	130	0.14	0.54	481.4
5. Egypt	143	105	125	0.75	0.51	87.4
6. Other countries	510	550	680	2.67	2.80	133.3
Total ...	1,760	1,880	2,340	9.2	9.6	132.9
e. *Europe*						
1. Western Europe	3,080	2,960	3,620	16.13	14.89	117.5
2. Eastern Europe	790	470	690	4.14	2.82	87.3
Total ...	3,870	3,430	4,320	20.3	17.8	111.1
f. *Other Regions*						
1. Oceania	570	500	700	2.99	2.88	122.8
2. Antarctic (Whale oil) ...	436	334	332	2.28	1.37	76.1
3. Undistributed above ...	250	250	250	1.31	1.03	100.0
Total ...	1,260	1,080	1,280	6.6	5.3	102.1
g. World Total (Excluding U.S.S.R.)	19,100	20,210	24,300	100.0	100.0	127.4

Note:—Totals computed from unrounded data.

a. Preliminary.

b. Western Europe includes all European countries except Albania, Bulgaria, Czechoslovakia, Eastern Germany, Hungary, Poland and Rumania.

c. Rough estimate, based partly on trade data, for hempseed, perilla, mowrah, teaseed, nigerseed, poppy seed, shea-nuts, rice-bran, kapok, stillingia, safflower, grape-seed, murumuru, tucum-kernel, tobacco-seed, cashew shell and nut, and other minor oils.

Source:—S.P.C. Year Book and Buyers' Guide, Page 12, 1957.

TABLE V

World Exports of Primary Oils and Fats (by Commodities) Metric Tons '000

(In terms of oil or fat)

	Pre-war (Average) 1934-38	1955	1956 Partly estimated	1957 Forecast
I. VEGETABLE OILS & FATS				
Copra and coconut oil	1,057	1,189	1,323	1,351
Palm Kernels	320	386	397	394
Palm oil	447	546	555	546
Groundnuts	826	796	810	817
Soyabeans	432	486	732	766
Cottonseed	189	378	377	313
Linseed	572	454	350	540
All other vegetable oils	523	481	490	604
II. ANIMAL FATS				
Butter (fat content)	500	461	464	391
Lard	173	326	356	295
Tallow etc.,	162	711	817	785
III. MARINE OILS				
Whale oil (Including sperm)	507	470	477	467
Fish oil (Including liver)	121	189	195	169
Total	5,829	6,873	7,343	7,438
U.S.-retained imports of above commodities	960	490	435	435
Quantity available to Europe and rest of the world	4,869	6,383	6,908	7,003

TABLE VI

Share of Vegetable Oils and Fats in World Exports of Primary Oils and Fats

	Exports in Metric Tons (000s).				Per cent of total		Export Index for 1957 (Pre-war =100)
	Pre-war (Average) 1934-38	1955	1956 Partly estimated	1957 Forecast	Pre-war	1957	
1. Vegetable oils and fats	4,366	4,716	5,034	5,331	74.91	71.66	121.1
2. Animal Fats	835	1,498	1,637	1,471	14.32	19.77	176.2
3. Marine oils	628	659	672	636	10.77	8.55	101.3
Total	5,829	6,873	7,343	7,438	100.00	100.00	127.7

TABLE VII

World Exports of Primary Oils and Fats by Producing Areas Metric Tons (000s.)

	Pre-war (Average) 1934-38	1955	1956 Partly estimated	1957 Forecast
United States of America	100	1,795	2,154	1,934
Other America (excluding Argentina and Uruguay) ...	133	208	204	379
Philippines	348	597	727	756
Portuguese Africa	62	86	93	92
Belgian Cango	97	224	226	225
Argentina and Uruguay	577	216	133	269
British West Africa ... ... — ...	455	662	697	621
French West and Equatorial Africa	298	254	323	358
Other Africa	212	210	256	306
India and Ceylon	589	503	279	273
Malaya	132	104	114	109
Indonesia	529	310	331	326
Australia and Oceania	363	457	483	472
China and Manchuria	742	278	328	333
Other countries (Including Europe)	685	499	518	518
Whale oil (Antarctic & Arctic)	507	470	477	467
Grand Total	5,829	6,873	7,343	7,438

Note:—Pre-war to 1955: Compiled from official statistics.

1956: Official statistics and Unilever estimates.

1957: Unilever estimates.

Source:—From addresses by Faure published in technical literature, abstracted in Vanaspati Manufacturers Association (India) circulars.

TAB

World Production of the M

	Conversion factor[a] from seed to oil, per cent	1938-39 (1939)		1948-49 (1949)	
		As seed	Oil equivalent	As seed	Oil equivalen
					(Thous
a. *Edible*					
1. Groundnuts	31	8,518	2,641	10,057	3,118
2. Cottonseed	18	11,715	2,109	11,283	2,031
3. Soyabeans	15	12,620	1,895	15,884	2,388
4. Sunflower seed	25	2,732	683	4,226	1,057
5. Sesame seed	45	1,422	640	1,869	841
6. Olive oil[b]	...	...	829	...	517
b. *Edible Industrial*					
1. Copra	63	2,460	1,550	2,344	1,477
2. Palm kernels[c]	45	640	288	764	344
3. Palm oil[c]	...	...	545	...	547
c. *Industrial*					
1. Rapeseed	35	3,803	1,331	4,549	1,592
2. Linseed	33	3,243	1,070	3,868	1,276
3. Castor seed[d]	43	292	126	411	177
4. Tung oil[e]			70		115
Total edible (A)			8,796		9,945
Total edible industrial (B)			2,383		2,365
Total industrial (C)			2,597		3,160
Total (A+B+C)			13,776		15,470

a. These figures represent the world average yield of oil in commercial crushing.

b. Edible and unedible; the edible oil for the four periods was 744, 465, 1012 and 1090.

c. Commercial production.

d. Excluding the Soviet Union and China.

e. Excluding the Soviet Union.

f. Estimates.

eed Crops (1938-39 to 1956-57)

Quinquennial average of 1951-52 to 1955-56 (1952 to 1956)		1956-57 (1957)		Share of individual oilseed (as oil equivalent) in total production of all oilseeds and oils (as oil equivalent), per cent			
As seed	Oil equivalent	As seed	Oil equivalent	1938-39	1948-49	Average of 1951-52 to 1955-56	1956-57
Tons)							
10,816	3,355	12,822	3,975	19.17	20.16	18.49	18.92
15,004	2,701	15,166	2,730	15.31	13.13	14.89	13.00
18,853	2,828	23,786	3,568	13.76	15.44	15.59	16.99
4,976	1,244	6,905	1,726	4.96	6.83	6.87	8.22
1,920	864	1,971	887	4.65	5.44	4.76	4.22
...	1,123	...	1,206	6.02	3.34	6.19	5.74
2,963	1,866	3,250[f]	2,047	11.25	9.54	10.29	9.75
861	388	905[f]	407	2.09	2.22	2.14	1.94
..	654	...	670[f]	3.96	3.54	3.61	3.19
5,166	1,808	5,788	2,026	9.66	10.29	9.97	9.65
3,091	1,020	4,457	1,471	7.77	8.25	5.62	7.00
417	179	423	182	0.915	1.144	0.989	0.867
...	105	...	105[f]	0.508	0.743	0.579	0.500
...	12,115	...	14,092	63.84	64.28	66.77	67.08
...	2,908	...	3,124	17.30	15.29	16.03	14.88
...	3,112	...	3,784	18.85	20.43	17.16	18.02
	18,135	...	21,000				

TABLE IX

Production Index of the Main Oilseeds and Oils Compared to 1938 Year[a]

	1938–39 (1939)	1948–49 (1949)	Quinquennial Average 1951–52 to 1955–56 (1952–56)	1956–57 (1957)
A. Edible				
1. Groundnuts	100.0	118.0	127.1	150.6
2. Cottonseed	100.0	96.3	128.1	129.5
3. Soyabeans	100.0	126.0	149.3	188.4
4. Sunflower seed	100.0	154.7	182.2	252.7
5. Sesame seed	100.0	131.4	135.0	138.6
6. Olive Oil	100.0	62.4	135.4	145.4
B. Edible-Industrial				
1. Copra	100.0	95.3	120.4	132.0
2. Palm kernels	100.0	119.3	134.6	141.4
3. Palm oil	100.0	100.3	120.0	122.9
C. Industrial				
1. Rapeseed	100.0	119.6	135.8	152.3
2. Linseed	100.0	119.3	95.3	137.5
3. Castor seed	100.0	140.7	142.8	144.8
4. Tung oil	100.0	164.3	150.0	150.0
Total Edible (A) ...	100.0	113.1	137.7	160.2
Total Edible-Industrial (B) ...	100.0	99.2	122.0	131.1
Total Industrial (C) ...	100.0	121.7	119.9	126.9
Total (A + B + C)	100.0	112.3	131.9	152.8

[a] The index figures are worked out from the figures of oil equivalent in Table VIII.

TABLE X

Net Export of the Principal Vegetable Oils and Oilseeds by Commodities

	Quantity exported (as oil equivalent) (Thousand Long tons)				Export of oil as per cent of total export of seed (as oil plus oil)				Net exports of individual commodities expressed as index (1938=100)				Share of individual commodities in total of all oils and oilseeds (as oil equivalent), per cent			
	1938	1948	1951–55 (Average)	1956	1938	1948	1951–55 Average	1956	1938	1948	1951–55 Average	1956	1938	1948	1951–55 Average	1956
A. Edible																
1. Groundnut ...	942	482	584	785	5.4	22.2	36.6	27.4	100.0	51.2	62.0	83.3	21.69	17.13	14.79	16.19
2. Cottonseed[a] ..	171	98	216[b]	370[b]	23.4	42.9	73.6[b]	81.9[b]	100.0	57.3	126.6	216.4	3.94	3.48	5.48	7.63
3. Soyabeans ...	380	71	334	696	10.3	52.1	28.9	43.5	100.0	18.7	87.9	183.1	8.75	2.52	8.46	14.35
4. Sunflower ..	5	64	50	28	0	85.9	74.8	50.0	100.0	128.0	100.0	560.1	0.12	2.28	1.27	0.58
5. Sesame ...	42	27	48	56	4.8	0.0	4.2	1.8	100.0	64.3	113.3	133.4	0.97	0.96	1.21	1.13
6. Olive ...	120	75	81	108	100.0	100.0	00.0	100.0	100.0	62.5	67.2	90.0	2.76	2.67	2.04	2.23
B. Edible-Industrial																
1. Coconut ..	1,170	895	1,126	1,299	26.5	20.7	24.2	26.6	100.0	76.5	96.3	111.0	26.97	31.81	28.51	26.80
2. Palm kernel ...	309	310	368	390	0.0	5.1	6.0	11.3	100.0	100.3	119.1	126.0	7.11	11.03	9.31	8.04
3. Palm ...	488	366	525	548	100.0	100.0	100.0	100.0	100.0	75.0	107.6	112.3	11.23	13.00	13.29	11.31
C. Industrial																
1. Rapeseed ...	33	36	60	59	24.2	83.3	46.4	54.2	100.0	109.1	183.0	178.8	0.76	1.28	1.53	1.22
2. Linseed ...	533	210	400	353	0.4	57.2	71.2	48.4	100.0	39.4	75.1	66.2	12.27	7.46	10.14	7.28
3. Castor ...	82	103	114	107	12.2	24.3	48.9	59.9	100.0	125.6	139.3	130.5	1.89	3.66	2.89	2.21
4. Tung ...	69	76	44	50	100.0	100.0	100.0	100.0	100.0	110.2	63.4	72.5	1.59	2.70	1.10	1.03
Total Edible (A)	1,660	817	1,313	2,043	15.4	38.7	44.9	46.2	100.0	49.2	79.1	123.0	38.21	29.04	33.24	42.13
Total Edible-Industrial (B)	1,967	1,571	2,019	2,239	40.6	36.2	40.6	41.9	100.0	79.9	102.6	113.8	45.29	55.85	51.11	46.17
Total Industrial (C)	717	425	618	569	12.4	59.1	66.7	55.7	100.0	59.3	86.3	79.4	16.50	15.11	15.66	11.73
Total, all oils and oilseeds	4,344	2,813	3,950	4,849	26.3	40.4	46.1	45.4	100.0	64.8	90.9	111.6	100.00	100.00	100.00	100.00

a. Excluding Pakistan which has become a net importer since 1955.

b. Excludes gift shipments from the U. S. A., estimated at 23,000 tons in 1955 and 2,000 tons in 1956.

TABLE XI

Trends in Consumption[c] of Edible Oilseeds and Oils (in Total Oil Equivalent) in Principal Oilseeds Producing Countries, Commodity-wise

Oilseed	Production of seed[a] (oil equivalent)		Net exports of seed & oil[b] (oil equivalent)		Consumption of seed & oil (oil equivalent) in producing countries		Index for 1956 compared to 1938 as 100			Consumption as per cent of production	
	1938-39 1939	1956-57 1957	1938	1956	1938	1956	Production[d]	Consumption	Export[b]	1938	1956
	(Thousand long tons)										
Groundnut ...	2,641	3,975	942	785	1,699	3,190	150.6	187.7	83.3	64.3	80.3
Cottonseed ...	2,109	2,730	171	370	1,938	2,360	129.5	121.7	216.4	91.9	68.7
Soyabean ...	1,895	3,568	380	696	1,515	2,872	188.4	189.5	183.1	79.5	80.5
Sunflower seed ...	683	1,726	5	28	678	1,698	252.7	250.5	560.1	99.3	98.4
Sesame seed ...	640	887	42	56	598	831	138.6	139.0	133.4	93.4	93.7
Olive oil ...	829	1,206	120	108	709	1,098	145.4	154.9	90.0	85.5	91.1

a. From Table VIII.

b. From Table X.

c. It is assumed that seed and/or oil not exported is used within the main producing countries for domestic uses, either as seed for edible or non-edible uses, for seeding, cattlefeed, etc., or in the form of oil and cake as cattlefeed or fertiliser.

d. From Table IX.

PROCESSING OF COTTONSEED AND COTTONSEED OIL–A REVIEW

PART II: THE PROGRESS OF THE COTTONSEED OIL INDUSTRY IN THE MAJOR PRODUCING COUNTRIES.

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In Part 1, the place of cottonseed oil amongst the other edible oils was considered and the general trends in production and trade of cottonseed were discussed. In this part, the trends in production of cottonseed and trade in cottonseed and cottonseed oil in the important countries of the world are discussed. The present position of the Indian industry is outlined and some economic and technological aspects relating to the development of the cottonseed oil industry discussed.

Acreage and Production

The world area under cotton fluctuated between 77 million and 86 million acres during the period from 1938-39 to 1956-57. The U.S.A. which had maintained for several years the largest area under cotton, changed this status after 1954-55. The peak of 28.2 million acres (1951-52) during recent years in U.S.A., was reduced to 19.8 million acres in 1954-55, and to 16.8 million acres in 1956-57.

Area under cotton in India took an upward trend beginning in 1952-53 and reached the peak of 20.2 million acres in 1955-56, thereby reaching the first rank in the world in respect of area. There was a decrease in 1956-57 to 19.8 million acres but this was still 3 million acres greater than in the U.S.A. The area under cotton, production of cottonseed, and yield of seed in lbs. per acre, are given country-wise in Table XII, arranged in the order of decreasing production for 1956-57.

World production of cottonseed fluctuated between 11 and 12 million long tons between 1938-39 and 1950-51. In 1951-52, it increased to 14.4 million tons, fluctuated around 15.1 million tons in the next two years, reached the peak of 15.6 million tons in 1955-56, and again showed a slight decline to 15.2 million tons in 1956-57. The world average yield of seed per acre increased from 340 lbs. in 1938-39 to 435 lbs. in 1956-57.

Commonwealth countries account for nearly one-third of the world acreage and one-sixth of the world production of cottonseed. India accounts for one fourth of the total world acreage and three-fourths the acreage in the Commonwealth. But due to the low yield of cottonseed per acre in India, which stands at 187 lbs. per acre compared at 600 to 100 lbs. per acre in the Soviet Union, U.S.A., Egypt, Mexico, Sudan, and Peru, and El Salvador, Nicaragua, and Guatemala in Central America, production of seed is only one-ninth of the world production; and despite higher acreage, India ranks below the U.S.A. and the Soviet Union in production. The yield of cottonseed per acre is the lowest in the cotton-producing countries of the world excepting Uganda, Mozambique, and S. Rhodesia and Nyasaland. Production of cottonseed in China was higher than in India till 1955-56, but in 1956-57

Indian production was higher by about 1,10,000 tons. The yield of cottonseed per acre in China was 80 to 100% higher than in India, while in Uganda and Mozambique it was about 160-180 lbs. The acreage under cotton in S. Rhodesia and Nyasaland was comparatively very little and the yield of seed lowest at 100 lbs.

The world distribution of area under cotton and production of cottonseed, and the trends in different countries during 1938-39 to 1956-57 can be seen from the data in Table XII and from the curves of fluctuations in area (Fig. 4) and production (Fig. 5) for the different countries. During the decade 1938-39 to 1949-50, there was a decline in the area under cotton in almost all the countries in the world. The exceptions were Brazil, Mexico, Turkey, Argentina, Syria, Uganda, Iran, Spain, Mozambique and Paraguay, which each showed small increases of about 0.1 - 0.4 million acres. But the decrease in area under cotton was of the order of 1 to 8 million acres in the U.S.A., Soviet Union, India, China and Pakistan amongst the major cotton-producing countries. As a result, the world acreage under cotton came down from 77 million acres in 1938-39 to 64 million acres in 1948-49. In the nine years following, the reduction in area in the U.S.A. to 16.8 million acres in 1956-57 compared to 23.3 million acres in 1948-49 and 25.0 million acres in 1938-39 was significant. The Soviet Union, India, Pakistan and Egypt came back to the pre-war level. Amongst the major countries, Brazil and Peru increased acreage slightly, while in China, Mexico, Turkey, Sudan, Argentina, Syria, and Uganda, there was a substantial increase.

In the U.S.A., despite the decrease in acreage under cotton, there was a substantial increase in output of cottonseed caused by improvement in yield of seed per acre. In the Soviet Union, the yield of seed per acre was twice that for the U.S.A. even in 1938-39, and during the last two decades there has been a slightly greater increase in the yield per acre in the Soviet Union than in the U.S.A. The yield in lbs. per acre for the Soviet Union and U.S.A. in 1938-39 and 1956-57 were 689 and 396 in the former and 979 and 642 in the latter year. In consequence of this and the fall in area in the U.S.A., production of seed (in million long tons) increased only from 4.4 to 4.8 in the U.S.A. against from 1.6 to 2.2 in the Soviet Union.

Amongst the other important countries, the yield of seed per acre in 1956-57 was below the 1938-39 level in Brazil, Egypt and Uganda; at more or less the pre-war level in Argentina and Syria; and above the pre-war level in India, China, Mexico, Pakistan, Turkey, Sudan and Peru. In making this comparison, only the first fourteen countries in the order of production of seed in 1956-57, as arranged in Table XII, were considered.

Scope for Increase in World Production of Cottonseed Oil

The trends in the different countries in area under cotton, and the production and yield of seed, will help us understand two aspects of the possible impact on world trends in production and trade in cottonseed and oil that would follow development of the cottonseed oil industry in India. From the record production of cottonseed in the several countries listed in Table XII during the successive years 1948-49 to 1956-57 (data not shown), a maximum world production of 17.34 million tons of seed is possible if all the countries were to revert back to their record year levels during these 9 years. India is the only major producing country in which utilisation of the seed for recovery of oil has been insignificant and so long as the Indian cottonseed crushing industry does not make substantial progress, it follows that about 25% of the world production of seed remains unutilised for recovery of oil. An

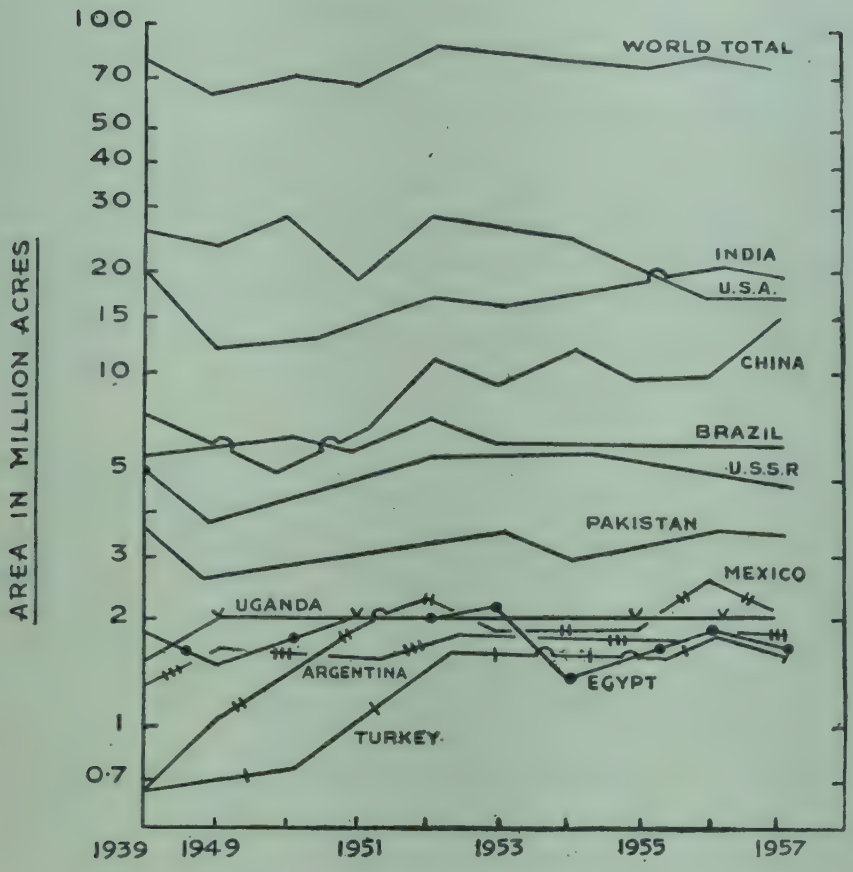
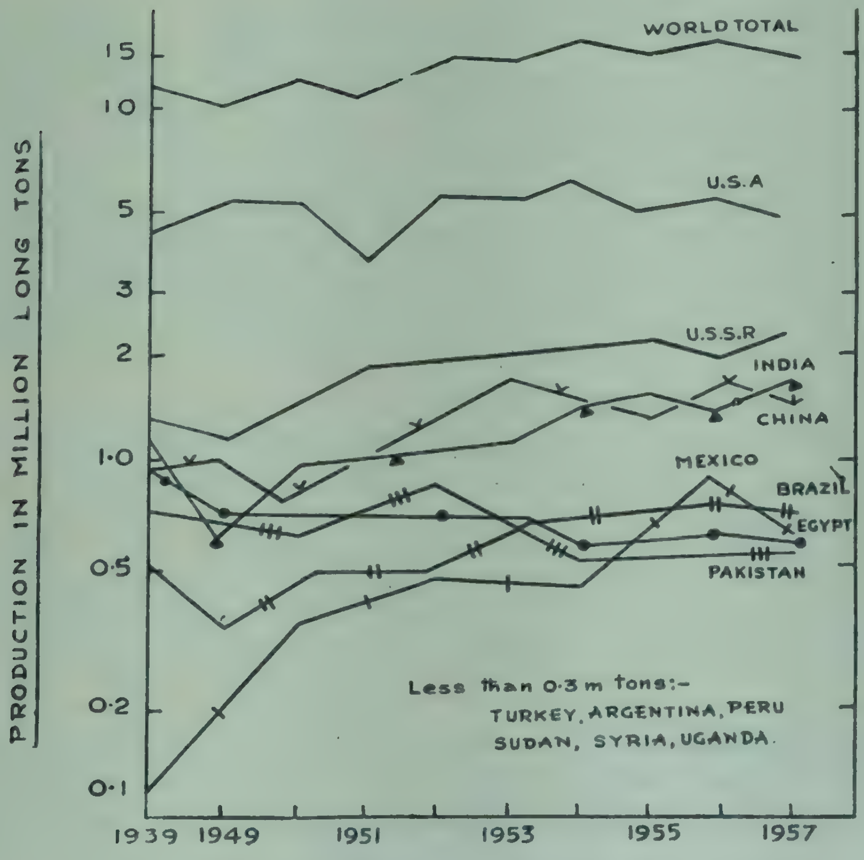


Fig. 4:— Area under Cotton in the Principal Producing Countries



Less than 0·3 m tons:-
TURKEY, ARGENTINA, PERU
SUDAN, SYRIA, UGANDA.

Fig. 5:— Production of Cottonseed in Principal Producing Countries

increase of 2.27 million tons of seed over the 1956-57 production, which is feasible, could give at most 306,000 tons of cottonseed oil through the crushing of 1.7 million tons of seed. Of this additional seed, 1.2 million tons would be the contribution from the U.S.A., being the difference between the peak production of 6.0 million tons in 1953-54 and 4.8 million tons in 1956-57, during which two years the area under cotton was 25.2 and 16.8 million acres respectively. If allowance is made for this increase in area and if it is assumed that the U.S.A. is unlikely to revert to a substantial increase in area from the present level of around 17 million acres, the extra oil obtainable from other countries would be a maximum of 144,000 tons from the 1.07 million tons of extra seed obtainable, of which 75% would be used for crushing.

The other extreme possibility is that all countries, economic conditions proving favourable, will increase the acreage under cotton to their peak year records during these 9 years. This would cause the world area under cotton to increase to 93.3 million acres from the 78.1 million acres of 1956-57. Taking the maximum yield of cottonseed per acre for the individual countries during these nine years, this increase in acreage by 15.2 million acres could lead to an increase in production of seed by 4.2 million long tons, out of which 3.2 million tons may well be crushed to yield an additional 5,56,000 tons of oil. This is a remote possibility in view of the declining trend in area under cotton in the U.S.A. On the other hand, if the area in this country remains steady around 17 million acres, the increase in area and yields possible in other countries could together give an additional yield of 1 million tons of seed through which a further 1,35,000 tons of oil could be obtained.

Compared to the above two possibilities, which are rather remote since the increase in production of by-product cottonseed is linked up with the trends in cotton which is the more important product of the cotton crop in economic value, there is a third alternative, *viz*., the contribution of over 1,50,000 tons to the world production of cottonseed oil through development of the Indian cottonseed crushing industry. This is more or less the same quantity obtainable by either of the remote possibilities considered above, and this avenue in India deserves serious consideration. Until a substantial increase in acreage under cotton or in yield of seed is brought about in the major producing countries, particularly in the U.S.A. the additional contribution from India will have significant economic importance. If a substantial improvement in the yield of seed per acre could also be effected side by side, the Indian industry would have added importance in the world cottonseed oil industry.

The net exports of cottonseed and its oil (in terms of total as oil equivalent) stood at 1,71,000 tons in 1938. Till 1954, the net exports were below the 1938 level, but there was sudden jump to 3,44,000 tons in 1954 due to the increase in export from the U.S.A. by 2,22,000 tons over the previous year. The continued exports from U.S.A. at this level in the subsequent two years was responsible for the sustained high level of net world exports which in 1956 reached 3,70,000 tons (Table XIII).

The exports of cottonseed in 1938 amounted to 7,80,000 tons (oil equivalent 1,40,000 tons). By 1948, the exports of seed came down to 3,14,000 tons (oil equivalent 56,000 tons), and in 1956 a slight increase of 3,64,000 tons (oil equivalent 65,000 tons) was registered. The exports of oil as such fell to 46,700 in 1948 as against 61,400 tons in 1938, but by 1956, export of oil rose to 3,12,000 tons.

In 1938, the U.S.A. exported 2,000 tons of oil and this country was a net importer of cottonseed oil in that year. By 1948, the U.S.A. became a net exporter and since 1954, it has contributed about 75% to 87% of the world exports of cottonseed oil (Table XIV).

Without the contribution from the U.S.A., the exports of seed and oil (in total oil equivalent) from the other countries in the world are still far below the 1938 level as could be seen from the following figures (in thousand long tons): 200 (1938), 88 (1948), 103 (1954), 140 (1955), and 105 (1956). This scarcity in world supplies of cottonseed oil was to a large extent responsible for the use of other soft oils in increasing proportions in the margarine and compound cooking fat industries, particularly in Western Europe.

Prior to 1954, exports of cottonseed oil from the U.S.A. were mostly to Canada, Mexico, and the Central American and South American countries. Beginning 1954, exports of oil from the U.S.A. reached a number of other countries in Western Europe, Africa, and Asia. Some of these were large sales made under "Public Law 480" for foreign currencies, and the other were private transactions. In 1956, West Germany imported 81,400 tons of oil from the U.S.A., followed by Argentina 70,100 tons, Spain 35,000 tons, Canada 14,200 tons, the Netherlands 12,900 tons, Turkey 9,900 tons, Israel, Italy and Chile 6,000 to 7,000 tons, and smaller quantities by the U.K., Algeria, Belgium, Bolivia, Columbia, Equador, Japan, Morocco, Peru, the Philippines, Switzerland and Venezuela. The U.K. received 22,000 tons in 1954, and in the same year Canada received 23,400 tons and the Netherlands 1,20,100 tons. In 1955, Chile received 19,700 tons, and Switzerland 12,100 tons. These figures indicate how the major consuming industries try to avail of the interchangeability in edible oils to suit the economic changes from year to year arising out of the supply-demand situation.

Table XIII shows that export of oil has assumed greater importance in recent years, compared to export of seed. In 1938 nearly 70% of the total exports of seed and oil (in oil equivalent) were as seed. This came down to 17% by 1956. In 1938, Egypt, Uganda Sudan, China and Manchuria, and Brazil were the major exporting countries, and of these, Brazil was the only country exporting oil in substantial tonnage, leaving aside the U.K. which was an importer of seed and exporter of oil. In 1956, Sudan, Nicaragua, Syria, Nigeria and Uganda accounted for almost the total exports of seed, and barring the U.S.A. the exports of oil from other countries were less than 8,000 tons individually. Egypt and the U.K. were the major importing countries for cottonseed from the Sudan.

In the U.S.A. cottonseed is the second-most important edible oil and about 92% of the total crop is crushed on an average. The growing use of solvent-extraction methods have also contributed towards higher yields of oil from seed crushed.

In Uganda, commercial crushing was of no importance in 1939. In 1955-56, it accounted for 69% of the crop, and 91,000 tons of seed were crushed. In 1953-54, out of 1,65,000 tons of cottonseed crop, 1,47,000 tons were crushed. In consequence of the expansion of the crushing industry, exports in the form of seed have declined in importance.

Similar trends are indicated in Egypt, Brazil, and Peru. The crushing capacity in Pakistan is assessed at 60,000 tons annually. In China, in pre-war years, about 25% of the seed produced was crushed, and this has now increased substantially. Burma has greatly increased her crushing capacity and several Asian and South American countries are also taking steps in this direction.

In 1938, the U.K. accounted for two-thirds of the net world imports of cottonseed and cottonseed oil (as oil equivalent) of 161,000 tons, and Germany imported less than 2%. In 1956, West Germany became the largest single importer accounting for 104,000 tons (in oil equivalent) out of total world net imports of 1,63,000 tons (in oil equivalent) and the share of the U.K. has dwindled to 26,000 tons or 16%. Canada and Japan imported 15,000 and 14,000 tons respectively in 1956 (Table XV).

Further, in pre-war years imports into the U.K. were almost completely in the form of seed; the 6,20,000 tons of seed imported in 1938 came down to 122,000 tons in 1956 (roughly one-third of this coming from Nigeria and one-third from the Sudan). The import of oil in 1956 was only 4,800 tons of which 3,800 tons was from India. (Table XVI). The Soviet Union and Eastern Europe together imported 30,000 tons of oil in 1955.

Relative Price of Cottonseed Oil and Groundnut Oil in the U.K.

Another significant change in the world cottonseed oil industry is in the economic value of cottonseed oil relative to groundnut oil. The U.K. was the major importer of cottonseed for domestic crushing during these years. Even in 1956 (barring West Germany, Argentina, Netherlands and Spain which have become interested in substantial imports of cottonseed oil only since 1953 or 1954), the U.K. was the major importer (in terms of oil equivalent). The price structure in the U.K. for cottonseed oil and groundnut oil gives a picture of the relative price trends in these two oils during the last two decades.

The fluctuations in the yearly average prices for these two oils (Table XVII) show that except in the year 1955, the price of cottonseed oil was consistently lower than the price of groundnut oil by £1-10 sh. to £17-0 sh. per ton. The price index (compared to 1938) rose to 733 for cottonseed oil as against 636 for groundnut oil. The quarterly prices for 1938 and 1954-57 are given in Table XVIII. During 1957, cottonseed oil was lower than groundnut oil by £2-3 sh. to £5-10 sh. per ton. This price difference should be interpreted in conjunction with the fact that the fatty acid industry is well established and that the soap industry has switched to the preferred use of inferior fatty stock such as acid oils, both of which permit economic utilisation of the soapstock from cottonseed oil refining.

Position in India

The estimated production of 1.733 million long tons of cottonseed in India (1956-57) consists of 1.158 million tons of the *desi* and 5,75,000 tons of the American variety of seed. The distribution of the cottonseed crop in India is shown in Table XX. More than half the production of seed is in Bombay State, and the major portion of this is of the *desi* variety.[3] By the end of the Second Plan period, the production of seed is expected to reach 2 million tons (Table XIX).

Recent systematic analysis of a large number of samples of different varieties of commercially-produced cottonseed from the various states indicate that, in general, both types of Indian cottonseed exhibit marked differences from the product produced in the U.S.A.[4-7] Between the *desi* and the American variety marked differences in composition and characteristics were also found. The *desi* varieties contain on an average less linters, oil and protein, and more moisture, than American-type seeds. Further these characteristics for American-type seed grown in India are lower than those of seed produced in the U.S.A.

It was suggested that because of these differences, suitable modifications in the storage and processing conditions would be necessary. It was also established that about 75% of *desi* seed are comparable to American-type seed in respect of lint and oil contents and hence could be processed economically along with the American-type of seed which forms roughly 25% of the total production of Indian seed. Thus about 82% of the Indian varieties of cottonseed appear to be economically processed for recovery of lint and oil.

The progress in the crushing industry has hitherto been very slow. About 8,000 tons of oil was produced in 1953 and this increased to 17,000 tons in 1957 (Table XXI). The indigenous vanaspati industry used as much as 8,500 tons of cottonseed oil in 1953, constituting 3.7% of the total raw oils used in that year (2,27,900 tons) for the production of vanaspati (1,91,600 tons). In the subsequent year, 5,100 tons of cottonseed oil were used in the production of 2,30,700 tons of vanaspati from 2,61,600 tons of all raw oils,[8] the increased usage of cottonseed oil arising out of the short supply of groundnut oil during 1952-54.

Beginning 1958, the vanaspati industry has decided to use progressively increasing proportions of cottonseed oil in vanaspati production, from 2.5% in 1958 to 5.0% in 1959, 7.5% in 1960 and 10.0% in 1961. This assured offtake is expected to facilitate the development of the indigenous cottonseed crushing and cottonseed oil refining industry. Reports indicate that the consumption of cottonseed oil in vanaspati manufacture during the first half of 1958 was at 4% of the raw oils used, or 6,090 tons.

The problems of the vanaspati industry are more economic than technical, and the industry may be in a position to use even larger quantities if the former are solved. One difficulty is to get regular supplies of washed and/or refined cottonseed oil in time to keep up production schedules. The other is the higher price that cottonseed oil commands in the Indian markets over groundnut oil resulting in an increase in vanaspati production costs. To promote the increased consumption of cottonseed oil in vanaspati and soap, these two aspects need considered solutions.

The relative cost of cottonseed and groundnut oil was discussed in an earlier paper.[9] A study of the fluctuations in the weekly prices of these two oils from October 1956 to September 1957 indicates that while the average price of groundnut oil (Rs. 1,523) was higher than that of cottonseed oil (Rs. 1,491) by Rs. 32 per ton, the price of cottonseed oil may be from Rs. 200 above or below that of groundnut oil at any time.

For regular use of cottonseed oil at an assured minimum level in an industry like vanaspati or soap, a constant lower price for cottonseed oil compared to groundnut oil, to cover the extra processing costs, will be necessary if this burden is not to be passed to the consumer. Considering the extra hydrogen consumption, and the longer hydrogenation and deodorisation times required when cottonseed rather than groundnut oil is used in vanaspati manufacture, a price difference of about Rs. 150 was suggested as reasonable by technologists. Early this year, cottonseed oil has been completely exempted from excise duty to encourage its use in Indian industries. While this is encouraging, it probably does not completely solve the problem. This aspect has to be kept in mind in considering the changing pattern in the consumption of raw material oils for the vanaspati and soap industries.

One reason for the limited supplies of cottonseed oil to the Indian consuming industries is the tendency to divert the limited production to exports in order to avail of the higher economic value whenever possible. At 10% levels in vanaspati manufacture, about 42,500 tons of cottonseed oil can be used by the end of 1960-61. Besides, the soap industry may be able to consume a substantial quantity if there is a price advantage. The 18 units for crushing (8 units in operation and 10 units licenced or expected to be) would have a total capacity for 2,75,500 tons of seed and give a minimum of 35,000 tons of oil. A substantial increase in crushing capacity is possible in the near future if some of the economic aspects are tackled.

The problem for the crusher and refiner would be the economics of crushing, and the disposal of soapstock. A change from the current outlook of considering cottonseed as a feeding material is necessary. As a by-product of the cotton crop, it is linked with cotton in economic value and this would be the approach of the farmer. As an oilseed, it has to fit in with the price structure of oilseeds in general. Cottonseed cake, which constitutes the major by-product (70 to 80% on seed) of the crushing industry, should achieve parity in price with other cakes on the basis of its feeding value to the animal or its manurial value to the plant. Linters constitute the other economic by-product and are linked in price parity with the rayon and other polymer industries. And, as already pointed out, cottonseed oil prices must be in parity with the prices of other edible oils to have a sustained demand for all these by-products, either in domestic or export markets.

Thus the development of the cottonseed oil industry involves economic problems needing proper economic solutions, taking into consideration both the immediate needs and the long-range aspects. The fact of the cattle owner preferring to use whole seed in continuation of the established practice is a minor problem, as he may well be willing to fit in with the new trend if the economic and technological aspects are properly explained and the national interests placed before him.

To estimate the economics of crushing, more technological information is desirable. The ratio of the economic by-products—linters, oil, cake and hulls—and their quality, *viz.*, the composition and characteristics of the oil (in terms of saponification value and iodine value), the quality of oil (in terms of colour, free fatty acids, and gossypol content) and the protein content of the cake are all well-established to differ for the different varieties of *desi* and American-type seeds. In estimating the economics of crushing projects in different producing regions, using local varieties of seeds, an understanding of these ratios according to the variety of the seed would be useful.

Suggestions for Future Research

The usual practice in Indian work is to give average values and ranges. If instead individual values for different samples from the same type of seeds are given, a study of the correlations between the constituents could lead to a more realistic understanding of the economics. It would then be easier to consider whether mechanical expression and/or solvent extraction would be more economical for processing at any particular location. It is suggested that the workers in the field should either work out the correlations from their data, or furnish the individual uncondensed results to enable others to study this aspect for the general benefit of the industry.

The use of linters in the polymer industries depends on the fiber qualities, one of which is the degree of polymerisation of cellulose. It would be interesting to study if the linters obtainable from the different varieties of seeds differ significantly in this respect.

Cake is the major by-product by tonnage in the crushing of cottonseed. Although oil has been the major economic by-product of oilseeds, it is worth realising that protein could as well constitute the major product and oil a by-product. This approach would be of particular interest in the case of seeds low in oil like cottonseed. Planned research on economic industrial outlets for vegetable proteins is desirable, and the work done in this direction has been reviewed in some earlier papers.[10-12] A study of the composition of cottonseed proteins in indigenous varieties of seeds is desirable, both of the protein as a natural polymer, and its utilisation, not only in terms of amino acid composition, but also in terms of the actual *polymer* units as they exist in the seed and in the processed cake.

On the basis of the characteristics of Indian varieties of cottonseed oil published by Murti and colleagues,[5-7] specification limits for Indian cottonseed oil were earlier suggested.[9] A much wider range of 86.7 to 114.1 for iodine value and 183.4 to 206 for saponification value is indicated as the natural limits for Indian crude cottonseed oils, against the Indian Standard Specifications figures of 105-112 and 190-198 respectively (for both refined oil and washed oil). At the time the above specifications were drawn, much information was not available on oil from *desi* varieties of seed; in view of the scope for commercial production of oil from these seeds also, the specifications need reconsideration.

Another aspect to be considered is the alternative feed material to supply the energy requirements of cattle. By offering cake instead of the whole seed, the cattle would have less supplies of energy, weight for weight. Would it not be necessary to meet the extra energy requirements in the feed of the cattle equivalent to the difference in oil removed? Higher quantities of other rations would be necessary to provide this energy and maintain the same total energy input. What alternative feeding materials could be supplied to equalise the energy content of 1,50,000 tons of oil proposed to be recovered from the seed? This aspect also may have to be studied, and the cattle owner would be interested in comparing the cost of the substituted rations with whole seed ration to reckon the economic advantage to him in this deal.

It is believed that the extra oil now fed in the seed is not utilised by the animals for nutrition, that it is not all metabolised and merely excreted. It is also stated that this fat will interfere with the normal production of fat in the animal, and that it must therefore be regarded as definitely abnormal, if not almost pathological.[13] While it is admitted that cake is a better nutrient than whole seed, it would have to be considered whether the substitution of a pound of cake for a pound of whole seed would meet the energy requirements of the animal without the necessity of either increasing the quantity of cake to more than one pound or giving additional quantities of other rations.

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TABLE XII

Area Under Cotton and Production and Yield per Acre of Cottonseed in Principal Producing Countries[a]

	Area under cotton (thousand acres)			Production of cottonseed (thousand long tons)			Yield of cottonseed (lb./acre)		
	1938-39	Quinquennial Average 1951-52 to 1955-56	1956-57	1938-39	Quinquennial Average 1951-52 to 1955-56	1956-57	1938 to 1939	Quinquennial Average 1951-52 to 1955-56	1956 to 1957
1. United States	25,018	23,584.2	16,833	4,420	5,531.4	4,828	396	525	642
2. Soviet Union	5,122	5,710.0	5,100[e]	1,575	1,978.2	2,230[e]	689	776	979
*3. India ...	19,931	17,618.6	19,843	1,300	1,287.0	1,653	146	164	187
4. China	7,334	9,850.0	10,500[e]	960	1,540.0[e]	1,540[e]	293	350	329
5. Brazil ...	5,700	6,558.0	6,100[e]	940	754.2	720[e]	369	264	264
6. Egypt ...	1,852	1,799.2	1,715	700	689.8	622	847	859	813
7. Mexico ...	642	2,096.6	2,144	116	577.4	618	405	617	646
*8. Pakistan ...	3,559	3,298.6	3,560	522	556.0	597	329	300	376
9. Turkey ...	680	1,546.2	1,532	120	284.4	289	395	412	423
10. Sudan ...	458	624.2	764	115	158.2	230	562	568	674
11. Argentina	1,005	1,457.4	1,542	140	248.2	216	312	382	314
12. Peru ...	474	519.8	556	139	153.2	177	657	660	713
13. Syria ...	54	478.8	673	13	113.4	160	539	531	533
*14. Uganda ...	1,205	1,584.8	1,589	121	131.4	125	226	186	176
15. Iran ...	404	445.6	585[e]	75	91.4	122	416	459	467
16. Greece ...	185	263.0	395	32	75.6	107	387	511	607
17. Belgian Congo ...	914	866.6	865	70	91.6	103	172	237	267
18. Spain ...	75[e]	236.6	500[e]	5[e]	40.2	100	149	381	448
19. Nicaragua ..	N.A.	147.6	178	2	48.0	73	N.A.	728	919
20. Fr. Equatorial Africa ..	N.A.	N.A.	N.A.	17	67.4	66	N.A.	N.A.	N.A.
*21. Nigeria[b] ...	N.A.	N.A.	N.A.	8	48.8	56[e]	N.A.	N.A.	N.A.
22. Mozambique	493[e]	658.0	725	17	52.8	52	77	180	161
23. El Salvador	2	77.0	94	2	26.8	44	2,240	779	1,048
24. Colombia ...	40	181.5[f]	164	4[e]	33.6	42	224	415	574
25. Burma ...	408	359.0	399	36	36.2	40	198	226	225

TABLE XII—*(Contd.)*

Area Under Cotton and Production and Yield per Acre of Cottonseed in Principal Producing Countries[a]

		Area under cotton (thousand acres)			Production of cottonseed (thousand long tons)			Yield of cottonseed (lb./acre)		
		1938-39	Quinquennial Average 1951-52 to 1955-56	1956-57	1938-39	Quinquennial Average 1951-52 to 1955-56	1956-57	1938 to 1939	Quinquennial Average 1951-52 to 1955-56	1956 to 1957
*26.	Tanganyika	220	227.2	320[e]	16	27.8	39	163	274	273
27.	Korea ...	578	304.4	285	80	35.0	33	310	258	259
28.	Roumania ...	10	452.2	278	2	96.6	33	448	479	266
29.	Bulgaria ...	136	124.0[e]	120[e]	13	35.0[e]	25	214	632	467
30.	Paraguay ...	120	159.2	160	11	24.8	24	206	349	336
31.	Iraq ...	79[e]	146.8[e]	143	6	12.2	18	170	148	282
32.	Guatemala ..	N.A.	32.2	34	N.A.	10.2	14	N.A.	709	922
33.	Angola	151	119.2	128	11	11.2	13	163	210	228
34.	Italy ...	91	97.6	112	16	13.6	13	394	312	260
*35.	South Africa	7	83.8	100	N.A.	9.2	12	N.A.	246	269
36.	Yugoslavia ..	7	32.4	32	1	4.2	4	320	290	280
*37.	S. Rhodesia & Nyasaland	93	72.4	45[e]	N.A.	1.6	2	N.A.	50	100
38.	Other Commonwealth countries ...	85	21.4	22	15	16.2	16	395	1,695	1,629
39.	Others ...	N.A.	N.A.	N.A.	95	91.0	110	N.A.	N.A.	N.A.
	Total for Commonwealth countries	25,100	22,906.8	25,479	1,932	2,076.0	2,500	177	203	220
	Total for other countries	52,032	58,693.6	52,656	9,733	12,927.8	12,666	419	493	539
	World Total	77,132	81,600.4	78,135	11,715	15,003.8	15,166	340	412	435

a. The countries are arranged in the order of production of cottonseed in 1956-57.

b. Commercial production.

c. South Korea only Post-war.

d. The figures under area represent Australia and British West Indies, the separate figures for the two countries being 66 and 19 for 1938-39; 8.4 and 13 for 1951-52 to 1955-56 average; and 10 and 12 for 1956-57 respectively.

e. Estimates.

* Commonwealth country.

N.A. Not available.

TABLE XIII

Net Exports of Cottonseed and Cottonseed Oil from Primary Producing Countries (1938-1956)

	1938	1948	1949	1950	1951	1952	1953	1954	1955	1956
	(Thousand tons, oil equivalent)									
Commonwealth										
Pakistan ...	...	30	15	27	10	6	1	...	b	b
Uganda ...	22[a]	...	13	12	9	10	12	8	5	8
Others ...	3	2	2	4	4	2	6	9	16	13
Foreign										
Argentina ...	..	7	4	13	8	...	...	...	...	..
Brazil ...	42	10	9	2	8	...	...	...	...	...
Egypt ...	66	2	1	6	b	b	15	3	...	b
Sudan ...	18	16	18	20	24	21	26	23	22	31
United States ...	...	14	53	64	29	49	36	258	259[c]	273[c]
Others ...	20	17	13	15	23	30	54	43	53	45
Total ...	171	98	128	163	115	118	150	344	355c	370[c]
Of which:										
Seed (as oil) ...	171	56	57	71	56	49	56	58	67	67
Oil ...	40	42	71	92	59	69	94	286	288c	303[c]
Total excluding Pakistan ...	171	68	113	136	105	112	149	344	355c	370[c]

a. Kenya and Uganda.

b. Net Importer.

c. Excludes United States gift shipments estimated at 23,000 tons in 1955 and 2,000 tons in 1956.

TABLE

Exports of Cottonseed and

	1938			1948		
	Seed	Oil	Total as oil equiv.	Seed	Oil	Total as oil equiv.
Commonwealth Countries						
1. United Kingdom ...	...	10.4	10.4	...	1.1	1.1
2. Hongkong	...	...	...	...	...	...
3. India	1	...	0.2			
4. Pakistan...		...	...	164	...	29.5
5. Kenya	...		..		0.1	0 1
6. Nigeria	7	.	1.3	5	...	0.9
7. Rhodesia & Nyasaland ...	1	...	0.2	1	...	0.2
8. Tanganyika	9	...	1.6	5	...	0.9
9. Uganda	123		22.1	1	...	0.2
10. Others	...	...	..	...	...	...
Total ...	141	10.4	35.8	176	1 2	32.9
Foreign Countries						
11. Angola	1	...	0.2	6	...	1.1
12. Argentina	...	...	..	...	7.1	7.1
13. Belgian Cango	...	0.7	0.7	...	1.6	1.6
14. Belgium	.	...	..	...		...
15. Brazil	61	30.8	41.8	...	9.9	9.9
16. Bulgaria	.	.	...	..	..	.
17. China and Manchuria ...	63	1.4	12.7	..	3.8	3.8
18. Egypt	330	7.1	66.5	...	5.0	5.0
19. Guatemala	...	...	...	...	...	...
20. Iran	...	...	...	...	.	...
21. Iraq	8	...	1.4	...	...	...
22. Japan	..	5.5	5.5	...	...	...
23. Korea	12	...	2.2	...	...	...
24. Lebanon	...	...	...	...	.	...
25. Mexico		...	..	...	1.4	1.4
26. Mozambique	1	...	0.2	28	...	3.0
27. Netherlands	...	...	...	...	0.1	0.1
28. Nicaragua	1	...	0.2	...	...	...
29. Peru	31	...	5.6	...	..	...
30. Roumania	...	...	...	...	...	...
31. Soviet Union	12	...	2.2	...	...	...
32 Spain[a]	...	...	...	...	...	...
33. Sudan	98	...	17.6	89	...	16.0
34. Syria	2	...	0.4	...	...	
35. Thailand	...	...	...	...	..	
36. Turkey	2	...	0.4	1	...	0.2
37. United States of America	...	2.0	2.0	5	14.6	15.5
38. Others	17	3.5	6.6	9	2.0	3.6
Total	780	61.4	201.8	314	46.7	103.2
Exports of seed (as oil) %			69.57			54.74
do oil, %			30.43			45.26

a. Estimated.

b. Quantities not known.

c. Approximate unofficial estimates.

XIV

Cottonseed Oil (Thousand Long Tons)

1954			1955			1956		
Seed	Oil	Total as oil equiv.	Seed	Oil	Total as oil equiv.	Seed	Oil	Total as oil equiv.
...	0.7	0.7	...	4.9	4.9	...	0.8	0.8
...	0.2	0.2	...	1.2	1.2	...	0.1	0.1
...	1.1	1.1	...	5.1	5.1	...	3.8	3.8
...	...	...	...	...	...	...	...	...
...	0.2	0.2	...	0.1	0.1	...	0.2	0.2
37	...	6.7	52	...	9.4	37	...	6.7
3	...	0.5	2	...	0.4	1	...	0.2
...	...	...	...	...	0.7	5	...	0.9
...	7.7	7.7	...	4.5	4.5	15	5.5	8.2
...	1.2	1.2	...	0.4	0.4	...	2.0	2.0
40	11.1	18.3	58	16.2	26.7	58	12.4	22.9
11	...	2.0	9	...	1.6	9	...	1.6
...	...	...	...	...		...	...	...
...	4.9	4.9	...	5.6	5.6	...	6.4	6.4
...	3.2	3.2	...	27.4	27.4	...	0.7	0.7
...	...	...	...	...	...	...	...	...
8	...	1.4	6	...	1.1	...	...	...
b	5.0^{c}	5.0	b	3.2^{c}	3.2	2^{c}	7.6^{c}	8.0
...	5.1	5.1	...	4.7	...	...	4.4	4.4
5	...	0.9	...	...	...	...	...	...
5	...	0.9	...	...		...	...	...
...	...	...	...	...	...	4	...	0.7
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	0.5	0.5	...	1.9	1.9	...	0.7	0.7
...	...	...	...	...	...		...	...
24	2.0	6.3	1	3.5	3.7	...	1.6	1.6
...	9.8	9.8	...	5.1	5.1	..	1.2	1.2
32	...	5.8	6.3	...	11.3	54	...	9.7
...	...	...	...	...	..	...	...	...
13	...	2.3	15	...	2.7	6	...	0.9
...	...	...	..	...	...	...	...	...
6	...	1.1	10	...	1.8	10	...	1.8
104	4.2	22.9	100	4.3	22.3	149	4.0	30.8
34	...	6.1	73	...	13.1	41	..	7.4
...	...	...	...	...	...	5	...	0.9
1	...	0.2	...	...	...	...	...	...
12	256.2	258.4	20	255.4	259.0	13	270.8	273.1
13	4.0	6.3	17	4.5	7.6	13	2.5	4.8
308	306.0	361.4	372	331.8	398.8	364	312.3	377.8
		15.13			16.82			17.32
		84.67			83.18			82.68

TABLE XV

Net Imports of Cottonseed and Cottonseed Oil Into Principal Purchasing Countries

	1938	1948	1949	1950	1951	1952	1953	1954	1955	1956
	(Thousand tons, oil equivalent)									
Commonwealth										
United Kingdom ...	107	24	37	36	36	26	54	50	56	26
Canada	7	6	30	41	14	29	2	25	13	15
India	...	27	15	22	9	1	1	a	a	a
Foreign										
Germany	3	1	5	8	5	2	9	38	87	104
Japan	10	1	1	8	4	6	6	10	12	14
Mexico	...	...	1	...	6	12	2	10	2	1
Netherlands	1	1	1	2	2	2	4	42	15	3
United States of America	33	a	a	a	a	a	a	a	a	a
Total	161	60	90	117	76	78	98	175	165	163

a. Net exporter.

TABLE XVI

Imports of Cottonseed and Cottonseed Oil (Thousand Long Tons)

	1938			1948			1954			1955			1956		
	Seed	Oil	Total as oil equiv.	Seed	Oil	Total as oil equiv.	Seed	Oil	Total as oil equiv.	Seed	Oil	Total as oil equiv.	Seed	Oil	Total as oil equiv.
Commonwealth															
1. United Kingdom	620	5.7	117.3	69	12.4	24.8	119	28.3	49.7	186	5.1	38.6	112	4.8	26.8
2. Canada ...	...	6.8	6.8	...	5.5	5.5	...	24.5	24.5	...	12.5	12.5	...	14.9	14.9
3. Cyprus ...	...	0.2	0.2	...	0.3	0.3	...	2.4	2.4	..	1.8	1.8	...	1.8	1.8
4. Hong Kong ...	...	...	...	...	...	...	...	5.9	5.9	...	1.0	1.0		1.0	1.0
5. India[a] ...	...	...	...	149	...	26.8	...	.	...	...	...	...	...	...	
6. Kenya ...	...	...	...	...	1.3	1.3	...	3.8	3.8	...	3.4	3.4	...	2.7	2.7
7. Malta[b] ...	5	2.0	2.9	5	2.1	3.0	1	2.4	2.6	1	0.6	0.8	...	...	..
8. Mauritius ...	...	...	...	...	...	...	...	4.3	4.3	...	2.4	2.4	...	3.3	3.3
9. Pakistan[c] ...	...	...	...	...	...	...	...	...	...	...	8.3	8.3		8.1	8.1
10. South Africa ...	...	...	...	5	...	0.9	...	...	...	...	..	...	...	...	...
11. Others ...	4	0.7	1.4	6	1.4	2.5	2	2.0	2.4	2	0.8	1.2	3	1.2	1.7
Total ...	629	15.4	128.6	234	23.0	65.1	122	73.6	95.6	189	35.9	70.0	125	37.8	60.3
Foreign Countries															
12. Irish Republic ...	...	1.0	1.0	...	...	...	...	2.7	2.7	...	2.6	2.6	...	2.0	2.0
13. Algeria ...	...	...	...	...	...	...	...	4.1	4.1	...	5.8	5.8	...	5.1	5.1
14. Argentina... ...	...	...	...	...	...	...	...	11.7	11.7	...	34.9	34.9	..	70.2	70.2
15. Austria ..	...	...	...	...	...	..	...	5.3	5.3	...	1.8	1.8	...	1.5	1.5
16. Belgium ...	...	0.6	0.6	...	0.7	0.7	...	8.5	8.5	...	27.2	27.2	...	3.4	3.4
17. Chile ...	50	...	9.0	...	...	...	...	10.0[d]	10.0	...	20.0[d]	20.0	...	6.8[d]	6.8
18. Colombia ...	...	...	...	...	0.2	0.2	...	...	..	...	3.5[d]	3.5	...	3.4[d]	3.4
19. Denmark ...	11	..	2.0	1	2.4	2.6	11	1.0	3.0	...	0.1	0.1	...	...	
20. Egypt ...	...	...	...	18	...	3.2	12	0.3	2.5	24	...	4.3	33	9.8	15.7
21. France ...	...	0.4	0.4	4	5.2	5.9	...	...	...	...	0.9	0.9	...	0.1	0.1
22. Germany ...	7	1.5	2.8	5	...	0.9	53	28.7	38.2	51	77.4	86.6	47	95.4	103.9

TABLE XVI—*(Contd.)*

Imports of Cottonseed and Cottonseed Oil (Thousand Long Tons)

	1938			1948			1954			1955			1956		
	Seed	Oil	Total as oil equiv.	Seed	Oil	Total as oil equiv.	Seed	Oil	Total as oil equiv.	Seed	Oil	Total as oil equiv.	Seed	Oil	Total as oil equiv.
23. Greece ...	...	...	...	3	...	0.5	21		3.8	17[d]	...	3.1	8	...	1.4
24. Israel ...	...	...	...	3	...	0.5	3	0.1	0.6	...	2.7	2.7	8	5.8	7.2
25. Italy ...	1	...	0.2	...	0.2	0.2	5	0.6	1.5	1	0.3	0.5	...	5.5	5.5
26. Japan ...	75	2.2	15.7	...	0.5	0.5	47	1.2	9.7	60	1.6	12.4	65	2.0	13.7
27. Lebanon ...	...	...	...	...	...	...	26[d]	...	4.7	40	...	7.2	37[d]	...	6.7
28. Mexico ...	1	...	0.2	4	...	0.7	6	8.9	10.0	11	..	2.0	4	...	0.7
29. Morocco ...	...	...	...	...	..	...	...	7.5	7.5	.	8.5	8.5	...	11.3	11.3
30. Netherlands ...	...	0.8	0.8	...	1.3	1.3	...	51.6	51.6	...	20.3	20.3	...	4.0	4.0
31. Spain ...	...	...	...	...	...	...	...	...	...	...	18.0	18.0	...	33.0	33.0
32. Turkey ...	...	...	...	...	...	...	...	...	...	...	12.3	12.3	...	0.3	0.3
33. Soviet Union & Eastern Europe	...	34.6	34.6	...	1.5	1.5	...	...	...	...	30.0	30.0	...	...	...
34. United States ...	4	2.9	3.6	4	3.5	4.2	4	10.0	10.7	2	13.5	13.9	2	10.7	11.1
35. Others ...	778	59.4	199.4	276	38.5	88.2	310	225.8	281.6	395	317.3	388.4	329	308.1	367.3
Import of seed (as oil), per cent			70.21			56.35			19.81			18.30			16.13
Import of oil, per cent ...			29.79			43.65			80.19			81.70			83.87

a. Twelve months commencing from 1st April of year shown.

b. Includes other edible oils prior to 1955.

c. Estimated.

d. Approximate.

TABLE XVII

Yearly Average Prices of Crude Cottonseed Oil and Crude Groundnut Oil in the United Kingdom (Per Long Ton)

	Crude Cottonseed oil[a]			Crude groundnut oil[b]		
	Yearly average		Price Index	Yearly average		Price Index
	£	sh.		£	sh.	
1938	18	7	100	21	15	100
1948	109	0	594	110	10	508
1949	109	0	594	110	10	508
1950	109	0	594	110	10	508
1951	123	10	673	128	8	590
1952	125	0	681	130	0	598
1953	129	10	706	139	7	642
1954	124	0	676	141	0	648
1955	112	0	610	109	5	502
1956	127	10	695	137	15	633
1957	134	10	733	138	5	636

a. In 1938 naked, ex-mill Hull; from January 1948 to May 1954 Ministry of Food selling prices, net naked ex-works or store; June-September 1954, net, naked ex-mill London; thereafter, washed oil, net, naked ex-mill Hull;

b. In 1938 naked, ex-mill Hull; from January 1948 to May 1954, Ministry of Food selling prices, net naked, ex-works or store; from June 1954, net naked, ex-mill London.

TABLE XVIII

Quarterly Average Prices of Crude Cottonseed Oil and Crude Groundnut Oil in the United Kingdom

(Per long ton) [a]

Quarter	1938				1954				1955				1956				1957			
	Cottonseed oil		Groundnut oil		Cottonseed oil		Groundnut oil		Cottonseed oil		Groundnut oil		Cottonseed oil		Groundnut oil		Cottonseed oil		Groundnut oil	
	£	sh.	£	sh.	£	sh.	£	sh.	£	sh.	£	sh.	£	sh.	£	sh.	£	sh.	£	sh.
January—March ...	19	11	24	3	138	10	150	7	111	0	107	13	127	0	122	10	157	0	162	10
April—June ...	17	17	21	2	128	0	154	0	104	0	103	10	115	0	150	10	131	0	133	3
July—September ...	18	7	21	12	116	0	142	0	120	0	117	13	128	10	128	10	125	10	129	7
October—December ...	18	7	20	5	115	0	118	0	112	10	109	0	140	10	150	0	124	10	128	7

a. See note under (a) and (b) in Table XVI.

The quarterly prices given for cottonseed oil were reproduced from page 52 of Ref. 2. The quarterly prices for groundnut oil were the averages of monthly prices for the particular quarter, the monthly prices being taken from page 36 of Ref. 2.

TABLE XIX

Production of Cotton and Cottonseed in India (1956-57) and Potential for Production of Cottonseed By-products

	Desi variety		American variety		Total		Estimated value in crores of Rs.
	Cotton '000 bales	Cotton-seed[c] (000) tons	Cotton (000) bales	Cotton-seed[c] (000) tons	Cotton (000) bales	Cotton-seed[c] (000) tons	
Bombay	2,449	817	346	115	2,795	932	
Punjab	163	55	692	230	855	285	
Mysore	176	59	259	86	435	145	
Madhya Pradesh	259	86	106	35	365	121	
Madras	102	34	188	63	290	97	
Rajasthan	163	54	57	19	220	73	
Andhra Pradesh	98	33	82	27	180	60	
Assam & Tripura	30	10	...	...	30	10	
Uttar Pradesh	30	10	...	...	30	10	
Total	3,470	1,158	1,730	575	5,200	1,733	
Seed to be retained for sowing, etc., at 15% of total production of seed	...	174	...	86	...	210	
Seed available for crushing	...	984	...	489	...	1,473	
By-products obtainable[a]							
1. Regional oil	...	108	...	63	...	171	24
2. Oilcake & husk	...	785	...	340	...	1,125	19
3. Linters (in bales of 400 lbs.)[b]	...	165	...	220	...	385	3.25
Total							46.25

a. The average yield for *desi* seed was reckoned at 11% of oil, 80% cake and husk, and 3% linters, as against 13% oil, 70% cake and husk, and 8.25% linters for American variety.

b. Of the 358,000 bales or 70,000 tons of cotton linters obtainable 15,000 tons would be first cuts and 55,000 tons would be second cuts.

c. Long tons.

Source: Reference 3.

TABLE XX

Statewise Production (Expressed as Percentages) of the Two Types of Cottonseed in India

State	Production of cottonseed, %		
	Total	*Desi* varieties	American varieties
Bombay	53.8	47.2	6.6
Punjab	16.4	3.2	13.2
Mysore	8.4	3.4	5.0
Madhya Pradesh	7.0	5.0	2.0
Madras	5.6	2.0	3.6
Rajasthan	4.0	3.1	1.1
Andhra Pradesh	3.5	1.9	1.6
Others	1.1	0.6	0.5
Total	100.0	66.4	33.6

TABLE XXI

Production of Cottonseed Oil in India

Year	Production (tons)	Imports (tons)	Exports (tons)	Used for vanaspati (tons)
1953	8,000	800	Negligible	8,500
1954	10,000	...	1,800	5,100
1955	12,500	...	5,800	500
1956	15,000	...	6,500	400
1957	17,000	...	7,700	1,200

2. ENCOURAGING COTTONSEED UTILISATION

By

B. VALLABHDAS PALOD

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The lack of a trade in crude, i.e., unwashed cottonseed oil constitutes the main hindrance to the quick development of the cottonseed crushing industry. Means of preserving crude oil in its pristine condition must be found by the addition of a chemical or mixture of chemicals. Undecorticated cake needs to be popularised as a cattlefeed.

The Major Problem

If we wish to see an immediate expansion and improvement in cottonseed crushing, we must see what problems are facing oil millers in crushing them. Crushing cottonseeds is no problem at all, as any oil miller can start it with some minor changes in the setting of the oil expeller and almost no extra expenses. But the problem of washing or refining the oil is standing in the way and so every oil miller cannot give the required encouragement to cottonseed crushing. There is no market for crude, *i.e.*, raw or unwashed cottonseed oil, which every oil miller can easily manufacture.

One way by which all oil millers, whether small or big, may be encouraged to start cottonseed crushing is that there should be market for crude cottonseed oil. If the cottonseed oil consumers start purchasing crude cottonseed oil, all the oil millers can start cottonseed crushing at once. Based on practical experience I can testify that the main reason why a market is not available for raw cottonseed oil is that after a short period, the acidity of the crude oil increases and it becomes almost impossible to wash or refine the oil. If this spoilt oil is refined or washed, it will need to be treated by an expensive procedure which cannot compete in the market.

Preserving Crude Oil

If the scientists of this country give their attention to this question which will not at all be difficult for them, I believe they can find a remedy for this trouble by way of suggesting a chemical or combination of chemicals which on mixing with the crude cottonseed oil will cause the acidity not to increase, and maintain the crude oil in the pristine state in which it was at the time of its crushing.

If the industrialists, who are at present consuming washed or refined cottonseed oil, purchase the chemicals mentioned, mix it with crude cottonseed oil and then wash it themselves, this will enable every oil miller to start cottonseed crushing at once without any hesitation.

There may be several other troubles and difficulties, but I feel certain that if such procedure is adopted, we will see a recordable improvement in the cottonseed crushing at once, provided the cost of such a mixture and of crude oil are competitive enough to lend encouragement for crushing.

Simpler Equipment

Next, I am of opinion that if we want to see an immediate progress in the cottonseed crushing industry, we must not insist on huge refining plants, or costly delinting and decorticating machines. All these may be used later on. In practical experiments for seven years, with this object in view, I was successful finally in washing the raw oil with an addition of only one heating tank, and can compete in the market with crushers having delinters, decorticators, and refining plants. But it requires trained technical hands, and hence if a market is found for crude cottonseed oil, the industry will take to crushing cottonseed without hesitation.

Popularising Undecorticated Cake as Cattlefeed

Government and military farms, etc. are purchasing only undecorticated cottonseed oilcake for using as a cattlefeed. It is said that undecorticated cottonseed oilcake is better as a cattlefeed even than whole cottonseeds. If this is true, the necessary advertisement and publicity should be made so that people in our country also start using this oilcake as cattlefeed.

3. ANOMALIES OF RAILWAY FREIGHT–RATE STRUCTURE AND ITS REPERCUSSIONS ON THE COTTONSEED CRUSHING INDUSTRY

By

B. M. JINDAL

(Bhagat Ram Amar Nath Oil Mills, Jullunder)

To encourage cottonseed crushing and achieve the targets laid down, it is necessary for the oil miller himself to popularise the use of oilcake as feed. A reduction in the railway freight on cottonseed is shown to be also essential for a healthy and widespread growth of the industry.

Importance of Railways

Railways play a very important role in the development of industries, transporting raw material and finished products to far-off places. Without this mode of transport a situation is bound to arise which will disrupt economy: in some parts there will be a glut of finished products, while in others a serious scarcity will result, shattering the country's economic structure. There are some industries which must be spread all over the country, instead of being localised, if they are to grow. For such industries, question of transport of raw material is more important than that of the finished products. Cottonseed industry belongs to this category as the initiative for the utilisation of one of its main products, *viz.*, oilcake, depends upon the personal contact of the industrialist with the farmer. The Planning Commission has well realised this point when it recommended a reduction in railway freight on cottonseed.

Oilcake Popularisation

The industry in India is yet in its infant stage. It utilises hardly 40-50,000 tons of cottonseed out of a total production of 14 lakh tons, the rest being used as a fodder which passes partly undigested in the cattle dung. The crushing of the total production of cottonseed in India to the extent of only 3.5% compares very badly with America which crushes 80 to 90% of its total production. This indicates the enormous wastage. This is specially strange when we find that hundreds of expellers remain idle for want of raw material. A substantial amount of foreign exchange can be earned even if 25% of the seed is crushed.

To attain this target the Government has taken some steps *e.g.*, abolishing the excise duty and export duty on cottonseed oil and encouraging its utilisation in vanaspati. But a close study of the industry will show that these steps, though welcome, will not cause growth of the industry. As the Chairman of the Vanaspati Association remarked in his recent presidential address, the sale of oilcake on suitable terms is more important for the growth of this industry than that of oil because 90% of the crushed product is oilcake.

Until and unless the oilcake becomes popular, the crushing target can never be achieved. Who is to do it? Certainly the mill owner, who will take pains to popularise the product. No commission agent can feel interested in such a tedious and hard job when he can well sell the cottonseed itself. For the mill owner it is an extra seed and gives him an extra opportunity to expand his works. Thus it is necessary that the mill owner should be in direct touch with the consumer. This can only be possible if the industry is scattered in every nook and corner of the country. The presence of the mills all over the country will itself create a favourable atmosphere for its propagation. Punjab, the biggest consumer of oilcake, substantiates this contention. United Punjab Industrialists incurred huge losses in the initial stages in order to propagate it. They had to do it because it was a matter of life and death for the industry. Steps like free distribution of the oilcake and distribution of leaflets were taken. Personal contacts were created with the consumers. They had to be persuaded that cottonseed oilcake is better and cheaper than whole cottonseed itself as a fodder.

Railway Freight Structure

Thus for the growth of the industry personal contacts with the consumers are most essential. For this the industry must be decentralised. This makes the question of transport of cottonseeds more important than that of oilcake. Railways can help a lot in this direction, but unfortunately the present freight-rate structure is a great hindrance.

It is known that the percentage of oil extracted from cottonseed comes to 10 to 15%, whereas in other oilseeds it amounts to 40 to 45%. This big difference in oil contents makes the railway freight on cottonseed and cottonseed oilcake comparatively much higher than for other oils and cakes, and in turn causes cottonseed crushing to be unpopular with oil industrialists.

Moreover the usual selling price of cottonseeds in our country is Rs. 8 to 11 per maund. The mill owners of non-cotton growing areas have to import cottonseeds from long distances. They have to pay railway freight even as high as Rs. 2 to 3-50 per maund. Thus the railway freight alone constitutes 25 to 35% (and sometimes ùpto 45%) of the cost of production of the finished products. This exhorbitant freight-rate is prohibitive to the industry and trade.

Need for Reduction in Freight on Cottonseeds

According to the recent classification by the Railway Board for freight purposes, oilcake has been placed in class 25A and cottonseeds in class 45A. The freight-rate on the latter is nearly twice that of the former. This puts the cotton-growing area industrialist in a privileged position. He has to pay much less to carry his products compared to the industrialists working in non-cotton growing areas for the transport of cottonseeds yielding the same quantity of finished products. Evidently the latter has to bear a high cost of production. How can the industry in these areas live or expand when the industry already yields only a marginal profit of 1 to 1.5%? Under these circumstances, what would be the incentive for starting mills in non-cotton growing areas? The industrialist knows that all his labour and capital will go to waste, for as soon as he starts getting the fruits of his hard labour in making the oilcake popular, the big capitalist from cotton-growing areas will immediately step in and dump his goods in the market. This not only mars the incentive for decentralised industry but also goes against our declared policy of a socialistic pattern of society.

This is the crux of the problem. In order to encourage the industry, to promote decentralisation and to attain a socialistic pattern, such anomalies in the railway freight structure in respect of oilcake and seed must be eliminated.

4. USE OF OPERATIONAL RESEARCH IN PLANNING OF RESEARCH STUDIES IN THE FIELD OF COTTONSEED

By
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The considerations that affect the choice of a research problem are personal, social, technical and that of research; any of these may become the dominating factor in the selection of a particular problem in a field of study. In order to correlate research with the target of the Second Five-Year Plan and coordinate it with industry, an experimental approach made in the field of cottonseed studies is briefly described here.

Preamble

Operational research has been broadly defined as the supply of quantitative data for executive decisions. For the purpose of this study a more generalised definition was taken.[1] This definition, apart from giving a definite perspective to research, also helped in the co-ordination of various phases and levels of research and in the integration of the social aspects with the technical.

Range of the Problem

The question of utilising cottonseed is a social as well as a technical problem. In the social field the problem covers the technical level of industry, existing practices in industry and agriculture, social prejudices (*e.g.*, the belief that the extraction of oil from cake reduces the nutritive value of the latter as a cattle feed), question of competition with other oilseeds, market prices and their fluctuation, and many other related problems. In the technical field, they range from the proper selection of varieties for sowing, conditions for higher yield of oil, problems connected with storage, delinting, dehulling, crushing, refining and storing, to the marketing of refined oil.

In the present approach, data on social aspects of the problems as well as information on the present acreage of different varieties, their oil contents and total production of cottonseed oil, was collected before further work was started. In the technical field the biological aspects of the problem were completely left out, as they were outside the facilities of the laboratory.

Organisation of Research

A unit consisting of the research workers engaged on different problems of cottonseed oil research, *viz.*, chemical engineer, statistician, an operational research worker and Director of the Laboratory, was formed. This constituted a team for research on the whole range of problems.

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* Research workers comprising the team on the problem in various capacities and at various stages were: S. Husain Zaheer, S. A. Saletore, K. S. Chari, S. R. Rao, V. P. Harigopal, V. R. Harwalkar, H. Gopalakrishnan, A. V. Venkatesham.

The attack on the problem was divided into four stages: (1) preliminary literature studies, (2) factory visits, (3) formulation of research programme and laboratory investigations, and (4) follow-up of the solution in factories.

Preliminary Literature Study

At the time the work was undertaken, two problems had been under study in the laboratory for quite sometime, the analysis of the cottonseed and the utilisation of foots. These were studied as independent problems purely from the technical aspects.

Preliminary study of the available literature revealed the different qualities of cottonseeds sown in different areas of India, different storage conditions and crushing practices. Since cottonseed was not considered as an oilseed, little attention had been paid to any of these aspects. Further, there was a definite opposititon from the administration and agriculturists for efficient extraction of oil from the cottonseed, as it was thought that extraction of oil from cake, through solvent-extraction or even by any other less exhaustive method, would render it valueless as a cattlefeed. Besides, business practices, such as marketing of seed and fluctuation in prices of other oilseeds, also affected considerably the crushing of cottonseed.

On the technical side the following main problems emerged: (i) oil content of various varieties, (ii) storage of seed and its effect on oil content, (iii) refining and storage problems of oil, and (iv) utilisation of foots.

These problems, it may appear, would be evident to any research worker in the field on preliminary study, and the working of a team may not be justifiable. A more detailed study of the individual aspects, however, would justify a different approach. Besides, experience in the application of results of research had shown that unless non-technical factors were studied with some degree of detail and thoroughness, they are likely to stand in the way of application of results. Consequently, they were studied and later experience showed that the approach was justifiable. The advantage of team-work from the very beginning lay in the appreciation of the most distant aspects of a problem during laboratory research and its proper coordination through a collaborative approach.

Factory Visits

In order to be fully appreciative of the technical level of the industry and aware of the minds of businessmen, the considerations that guide their actions, and the practices followed by them, it was necessary to visit various factories. Besides, it was also necessary for the laboratory research workers to be fully aware of the actual conditions in factories.

The visits were preceded by the drafting of a questionnaire. The questionnaire was very detailed and it was anticipated that data on all the aspects would be made available, and in visits to two factories, it was found possible to collect data on most of the items. The main points of the questionnaire were designed to yield data on:

1. Capital investment
2. Process costing (labour, technical supervision, amenities, etc.; workshop facilities)
3. Raw materials

4. Process, operations and machinery

5. Products

6. Whether the mill crushes other seeds than cotton

7. Management.

Information on some of these items was available, but its reliability was not certain and figures from different sources did not tally.

The factories crushing cottonseed in India can be grouped under:—(i) relatively modern, with a proper idea of processing and with technical facilities and personnel; (ii) relatively backward, with antiquated and inefficient equipment and little technical facilities and personnel; (iii) disorganised, like those which crush cottonseed only occasionally. The problems of each varied. Those under (i) were capable of utilising quality control methods and the traditional operational research study could probably yield greater results. It would not however, be useful to adopt these methods for (ii) and (iii). Data from organisations in categories (i) and (ii) were collected, but those under (iii) were not visited.

It will be evident that data collected through the questionnaire gave an idea regarding organisation of production in factories, *i.e.*, co-ordination of various units of operation and efficiency of production, methods of quality control of raw material and end products, technological level of the factory, and market research. The conclusions arrived at helped to formulate the research programme. In practice, after data had been collected from each of the factories visited, a report was written. The general points emerging out of each report were discussed and co-ordinated, and the research programme drawn up.

Formulation of Laboratory Research Programme

As a result of these preliminary studies and visits to factories the programme for laboratory research was formulated comprising:

(i) Storage of seed and its effect on oil content

(ii) Delinting, dehulling and crushing of cottonseed (pilot-plant studies)

(iii) Storage of cottonseed oil

(iv) Refining of cottonseed oil

(v) Utilisation of foots

In cases where this was possible, the data collected were statistically analysed, or experiments were designed to facilitate such analysis.

Besides these studies data were collected on:

(i) Acreage and production of different varieties of cottonseed in India

(ii) Oil content of different varieties
(iii) Utilisation of cottonseed oil
(iv) Machinery available in the country, its efficiency, etc.
(v) Marketing of oil and other products, and other business practices.
(vi) Administrative measures, social conditions and popular beliefs.

The progress made in many aspects of the research work is being reported elsewhere and need not be mentioned. A separate report on the other aspects has not been compiled but relevant data has been utilised in the formulation of the problem as well as the drawing of the conclusions.

Follow–up in Factories

This stage has not yet been reached. It would however be of some use to summarise here the chief features of what was proposed to be carried out under this head.

1. Selection of factories from amongst those visited for productivity studies, in order to help in increasing their efficiency and productivity and to gain their confidence for further work.

2. Translation of laboratory researches to pilot-plant and evaluation of their workability and efficiency quantitatively.

3. Passing the solution to factories and quantitative studies on productivity.

Conclusion

Since the final stage in the scheme of things has not been reached it is not possible to draw any definite conclusion with regard to the method followed and the procedure adopted. It may, however, be stated at this stage that as the work progressed it was felt by the members of the team that the work on the earlier stage has been of great help and use in the development of research on specific items. This may, however, be very subjective. The point in describing the basic idea, method and procedure has been to present it for criticism and advice before the scientists engaged in research in this field.

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5. A NOTE ON THE SCOPE OF OPERATIONS RESEARCH STUDIES IN COTTONSEED OIL INDUSTRY

By

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The use of statistical quality control in research on cottonseeds is illustrated with reference to data on storage studies.

Introduction

"Operations Research is the application of scientific methods, techniques and tools to problems involving the operations of a system so as to provide those in control of the system with optimum solutions to the problem."[1] Operations research studies had their foundation during World War II and the case studies of their application then reveal the immeasurable contribution it made towards Allied victory.[2] On the cessation of War and during the last ten years, a growing consciousness of the utility of the subject has lead to its extensive application in industry and scientific research. In this note an attempt is made to indicate the possible uses of the method of operations research in one aspect of the cottonseed industry, *viz.,* storage of cottonseeds.

The subjects for study under any operations research programme in industry usually concern the following:[3]

(i) Efficiency and productivity

(ii) Organisation of flow in factories

(iii) Methods of quality control, inspection, sampling and market research

(iv) Accidents

(v) Organisation of technological change

(vi) Absenteeism and labour relations

(vii) Transport

(viii) Stocking, distribution and handling

(ix) Communication.

Our study in the present note is confined to the first item, with particular reference to storage of cottonseeds.

Efficiency and Productivity in the Problem of Storage of Cottonseed

The yield and quality of the ultimate product, cottonseed oil, is dependent on the quality of the raw material (cottonseed) and the different production techniques, while the quality of the raw material itself depends on the agricultural conditions of the region where it is grown.

Storage studies can be undertaken on cottonseeds grown in different regions and under different conditions. Suppose in India the cottonseed is grown in say k regions. Denote by $T_1^1\ T_2^2 \ldots T_k^k$ cottonseeds grown in the different regions under sets of innumerable and influencing conditions, (i) = 1, 2,...k. Collect data on the oil characteristics like acid value, refining loss, colour of refined oil, colour of refined oil after bleaching, and percentage colour reduction initially and after storage of seeds for certain known periods, measurement being repeated a number of times for each region and under different sets of conditions for each region. Data will reveal the conditions under which optimum results could be achieved for cottonseeds grown in different regions for particular characteristics. According to the requirements, modifications could be introduced in the conditions of cultivation to promote optimum results in the characteristics desired. Further, the data will facilitate comparison between cottonseeds of different regions for various characteristics under the existing conditions.

Example (Empirical)

Consider the data in Table I giving the several characteristics mentioned for cottonseeds from 4 regions A, B, C and D, the number of observations of each being 5.

Statistical analysis of the data (Tables II and III) reveal that their productive capacities, as gauged by the characteristics measured, differ significantly for each of the 4 quality characteristics of the original seed. Similarly, analysis of the data for the original seed and after storage for stipulated periods will provide for comparison of the results and relative efficiencies. Recourse may further be made to precise statistical tests[4,5] to group the set of means under observation into homogeneous subsets where the analysis of variance test does not show significant difference between the means.

Conclusion

While the example constructed above shows only one aspect of application of scientific statistical methods, mention has to be made of the extensive applicability of the methods of statistical quality control in sampling, inspection and marketing research in the manufacture of cottonseed oil and its by-products. Stages of production of cottonseed oil may be taken up one by one and the scope of applicability of SQC methods indicated.

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TABLE I (a)

Data for Oil from Original Seed

	A					B					C					D				
Acid value ...	0.60	0.65	0.64	0.67	0.66	0.59	0.57	0.61	0.55	0.56	0.63	0.62	0.59	0.65	0.67	0.47	0.53	0.49	0.47	0.51
Refining loss, % ...	7.31	7.32	7.30	7.29	7.28	6.95	6.89	6.92	6.91	6.87	7.10	7.25	7.40	6.95	7.00	6.50	6.75	6.80	7.00	6.79
Colour of refined oil (Lovibond 1-inch cell, Y + 10 R) ...	61	60	59	60	62	59	61	58	57	59	61	63	60	59	60	57	55	59	56	55
Colour of refined oil after bleaching (expressed as above) ...	6.6	6.4	6.5	6.6	6.5	6.0	5.9	5.8	5.9	5.8	6.7	6.6	6.5	6.6	6.7	4.7	4.8	4.9	4.7	4.8

TABLE I (b)

Data for Oil from Seeds after Storage for One Year

	A					B					C					D				
Acid value ...	1.90	1.85	1.94	1.89	1.92	1.75	1.81	1.82	1.79	1.84	1.92	1.91	1.85	1.73	1.89	1.58	1.54	1.19	1.47	1.50
Refining loss ...	12.90	12.89	12.75	13.10	13.00	11.75	11.89	11.95	12.10	12.00	12.75	13.10	13.00	12.91	12.95	11.00	10.75	10.50	10.75	10.80
Colour of refined oil (Lovibond 1-inch cell Y + 10 R) ...	67	66	67	67	69	65	64	63	65	63	67	68	69	67	68	60	61	63	62	64
Colour of refined oil after bleaching (expressed as above) ...	25	27	26	25	26	24	25	25	24	25	23	25	24	24	25	20	22	21	20	21

TABLE

Showing the Calculations for Samples of Original Seeds in each Quality Characteristic where "X" Denotes the

	Acid Value					Refining Loss				
	A	B	C	D	Grand Total	A	B	C	D	Grand Total
1. $\lessgtr x$	3.22	2.88	3.16	2.47	11.73	36.50	34.54	35.70	33.84	140.58
2. $\lessgtr x^2$	2.08	1.66	2.00	1.22	6.96	266.45	238.61	255.04	229.16	989.26
3. $(\lessgtr x)^2/n$	2.074	1.658	1.997	1.22	6.88	266.45	238.60	254.90	299.03	988.14
4. Items 2–3	.006	.002	.003	...	.08	...	.01	0.14	0.13	1.12
5. $(\sigma)^2$	.0015	.0005	.00075	...	.0042	...	.0025	.035	.0325	.0063
6. σ	.0387	.0224	.0274	...	.0648	...	.05	.1875	.1803	.0794
7. $\overline{X}$	.644	.576	.632	.494	.587	7.30	6.91	7.14	6.77	7.03
8. C.V.%	6.01	3.89	4.34	...	11.04	...	.72	2.63	2.66	1.13

II

Individual Values, $\overline{X}$ and σ — the Mean and Standard Deviation of the Samples and C.V. the Coefficient of Variation

Colour of refined oil (Lovibond 1-inch Cell Y + 10 R)					Colour of refined oil after bleaching (Expressed as in the previous column)				
A	B	C	D	Grand Total	A	B	C	D	Grand Total
302	294	303	282	1181	32.6	29.4	33.1	23.9	119.0
18246	17296	18371	15916	69829	212.58	172.90	219.15	114.27	718.90
18241	17287	18362	15905	69738	212.55	172.87	219.12	114.27	708.05
5	9	9	11	91	.03	.03	.03	.03	10.85
1.25	2.25	2.25	2.75	4.789	.0075	.0075	·0075	.0075	.571
1.118	1.50	1.50	1.658	2.188	.08674	.08674	.08674	.08674	.7557
60.4	58.8	60.6	56.4	59.1	6.52	5.88	6.62	4.78	5.95
1.85	2.55	2.48	2.94	3.70	1.330	1.475	1.310	1.815	12.70

TABLE III

Analysis of Variance for Data of the Original Seeds for Different Quality Characteristics Measured

	Characteristics	Degrees of freedom	Sum of squares	Mean sum of squares	F.
Between Regions	Acid value	3	.07	.0233	37.28 **
A, B, C, D	Refining loss %	3	.83	.2767	15.266**
	Colour of refined oil	3	57	19	8.941**
	Colour of refined oil after bleaching	3	10.74	3.58	520.73 **
Within Regions	Acid value	16	.01	.000625	
A, B, C, D	Refining loss %	16	.29	.018125	
	Colour of refined oil	16	34	2.25	
	Colour of refined oil after bleaching	16	.11	.006875	
Total	Acid value	19	.08		
	Refining loss %	19	1.12		
	Colour of refined oil	19	91		
	Colour of refined oil after bleaching	19	10.85		

** Significant at 1%

6. STANDARDS FOR COTTONSEED AND ITS PRODUCTS

PART II. COTTONSEED LINTERS AND COTTONSEED CAKE

By

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In grading cottonseed linters, it is suggested that both the present U.S. system, which emphasises fibre length, resiliency, yield and colour, and the suggestions of Thoria and Ahmad[6] *which are based on the 'invisible loss' on passing through a Shirley Analyser and the α-cellulose content, be considered in India. For cottonseed cake grading, protein content, which chiefly defines the nutritive quality, is best stated separately from fat content, and cake condition also specified. Some aspects of evaluation and standardisation of cottonseed linters and oilcake are discussed in this paper.*

A. COTTON LINTERS

Cottonseed processing results in a unique and valuable by-product, cotton linters. No natural source of purer cellulose is known than linters. A nuisance at one time, cotton linters now bring in considerable revenue to the highly-developed cottonseed industry in the U.S.A. There is a growing demand for linters in India and the successful development of cottonseed crushing in this country greatly depends upon the production of high-quality linters.

Nature and uses

Linters are composed of the residual fibres of ginned cottonseed. They are generally a mixture, in varying proportions, of the long, convoluted, creamy-white fibre—the lint or cotton—and the short, smooth and generally coloured fibre—the fuzz.

Linters are consumed for the production mainly of (a) surgical cotton, textiles, paper, batting for mattresses, etc., for which the longer, first-cut fibres are generally used; and (b) 'chemical cotton' for a variety of industrial uses such as cellulose ethers and esters in explosives, plastics and synthetic fibres like rayon.

Each of these channels of consumption, particularly the chemical uses, has its own requirements and specifications for linters. Their grading and evaluation is thus of great importance.

Grading of Linters

The American system was evolved directly out of customer specifications and preferences. Linters are graded into seven basic groups—Grades 1 to 7, each group further subdivided according to regional characteristics, and boxes of these supplied for visual comparison.

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* 'Standards for cottonseed and its products'. K. T. Achaya, S. Raghavendar Rao, N. Sambasiva Rao, and S. A. Saletore, Indian Standards Institution Bull., 1958, *10*, 118 is treated as Part I.

Grade 1 (comprising the highest quality of linters with a preponderance of long fibres) and Grades 2 and 3 are usually obtained by "first-cut" delinting. The "second-cut" linters fall into Grades 6 and 7. The "mill-run", where the linters are cut from seed in a single operation, gives linters of Grades 3-5.

Factors Influencing Grading

Apart from customer preferences on which trading in linters was earlier based, the rational grading of linters into seven groups which was later evolved rested on the following characteristics:

(1) *Staple.* The relative sizes and distribution of lint fibres, obtained by different degrees of delinting, is referred to as the staple. This is a very important criterion of linter quality, as it affects the uses to which linters are put.

(2) *Foreign matter.* This consists of extraneous impurities like leaves, sand and dust particles, seed coat, hulls, etc. Their quantity depends upon the care exercised during seed cleaning and processing. In a detailed study of commercial Indian linters, Thoria and Ahmad[6] find that foreign matter greatly influences the quality of ∝-cellulose obtained from linters. Beyond a trash content of 17.5%, the yield of ∝-cellulose rapidly fall below a permissible minimum of 98% for chemical uses. The ash content, for which also maximum limits are rigidly specified, increases with the foreign matter. They also emphasise that pieces of crushed seed, undeveloped seed, etc., persist through the processing stages of chemical cotton and are highly detrimental to the quality and yield of ∝-cellulose.

(3) *Colour.* Linters vary in colour from white (usually the longer fibres) to cream, buff, grey and olive green (the shorter fuzz). Besides being naturally-coloured, linters get discoloured by weather and fungal damage.

(4) *Character.* This is an attribute which covers the length, uniformity and smoothness of the fibres, and is apparently the result of region, soil and variety of the seed.

(5) Thoria and Ahmad[6] find that the type of gins have a pronounced influence on linter quality, and that the quality of linters is better from a saw gin than a roller gin seed.

Indian Linters as Now Produced

Table I gives the results of analysis of Indian linters produced at the cottonseed pilot-plant of the Regional Research Laboratory, Hyderabad, of that cut by a local firm, and of imported linters.[1] The Indian linters are decidedly high in iron, ether-soluble matter and soda-soluble matter. They also generally contain a high percentage of foreign matter.[1,6] Table II gives the specifications generally laid down by different users of chemical cotton. All the specifications are of foreign origin, except for the Indian specification laid down by the Government Cordite Factory, Aruvankadu for the material for use in explosives. It may be pertinent here to point out that according to Van Wyck,[7] the U.S. system of grading emphasises the properties of linters for *batting* (used in mattresses and upholstery), where fibre length, resiliency, yield and colour are important factors. The yield of chemical cotton and ∝-cellulose, the kind and amount of foreign matter, and fibre length are critical in the manufacture of cellulose for the *chemical industry*, and these properties are not fully covered in the present U.S. system.

TABLE I

Analysis of Raw Linters

Sample	Shirley Yield %		Ash %	Silica %	Iron p.p.m.	Soda Soluble %	Ether Soluble %	∝-Cellulose in Purified Linters %
1. From cottonseed pilot plant of Regional Research Laboratory, Hyderabad ...	43.4	Max.	6.2	2.96	1600	21.6	1.40	99.5
		Min.	2.2	2.50	240	15.7	0.58	94.7
2. Local commercial mill ...	62.8		3.4		450	15.4	1.79	99.0
3. Imported linters ...	62.4		1.5		150	11.4	0.35	99.0

TABLE II

Typical Specifications for Chemical Cotton

For use in	Viscosity	Ash %	Iron p.p.m.	Silica %	Manganese %	Calcium %	∝-Cellulose %	Soda-Soluble %	Ether-Soluble %
1. Cellulose acetate for rayon	250 sec.	0.03	20	0.003	...	0.003	99.0	2.5	0.07
2. Cellulose acetate for plastics	350 sec.	0.03	20	0.003	...	0.003	99.0	2.5	0.07
3. Explosives									
(a) ...	5–50 poises	0.25	...	0.4	...	...	...	3.0 maximum	0.25 maximum
(b) ...	75 sec.	0.07	25	0.006	...	0.015	98.5	3.5	0.09
4. Lacquers	14.3 centipoises	0.05	13–25	...	..	...	98.5–99	3.0	0.06
5. Viscose for rayon	14 sec.	0.07	25	0.007	0.25	0.014	98.8	3.0	0.08

Series 1, 2, 3b, 5: Specifications from "How Chemcot is custom-made to your specifications," Southern Chemical Cotton Co., Chattanooga 10, Tenn., U.S.A.
Viscosity measured by Standard A.C.S. Method.
Series 3a. Specifications from Government Cordite Factory, Aruvankadu, Madras State.
Series 4. Specifications from M/s. Lansils Ltd., Lancaster, U.K. (private communication).

On the basis of figures for cottonseed production in 1956-57, about 26,000 tons of linters can potentially be produced. Both for internal consumption and for the export market, the adoption of standards for raising the quality of linters is essential. This is all the more true when it is realised that present linter quality is far from satisfactory.

A careful study of Indian linters, produced in 1939-40, led Thoria and Ahmad[6] to suggest an accurate basis for evaluation. Raw lint is passed through a Shirley Analyser and the treatment repeated on the trash obtained until no appreciable quantity of fibre is delivered. The difference in weight between the original sample and the weight of trash and purified material together is termed the "invisible loss." This loss, which represents the extremely short fibres, closely parallels the range of distribution of the smallest lint fibres (of size 1/16 inch) in the standard U.S. Grades 1-7. The same authors also derived a formula by which α-cellulose could be calculated from the "invisible loss", It was suggested that on the basis of "invisible loss" and α-cellulose, linters could be graded into groups which would define more accurately the linter characteristics than the present U.S. surface grading, in as much as they give information about both the α-cellulose content and the fibre size.

Recommendations for Production of Improved Indian Linters and Their Grading

With the anticipated rapid growth in the cottonseed crushing industry, as well as of the ancillary industries based on linters, like explosives, rayon, surgical cotton, lacquers, etc., the production of linters is bound to increase. In fact even the present requirement for the explosives and acetate rayon industries is hardly being met. The following suggestions may be considered for upgrading and increasing linter production:

(1) Desikan, Rao and Murti[3] have shown that a large percentage of "*desi*" seed contains over 3% of linters and should be delinted.

(2) All high-lintered cottonseed, particularly the American-type, should be delinted in two stages, first and second cut. It is the shorter second-cut fibres that are preferred for economy and ease of processing to chemical cotton.

(3) Proper seed cleaning cannot be over-emphasised. The detrimental effect of hull particles, seed coat, leaves, etc., on the quality of chemical cotton subsequently produced is out of all proportion to the quantity present.

(4) All delinting plants should have lint-cleaning and baling units.

(5) For grading purposes, two bases may be considered—the existing U.S. System, or the "invisible loss"-system of Thoria and Ahmad. A combination to include the advantages of both could usefully form a basis for rational standards.

(6) The Indian Standards' Institution could best deal with specifications for linters.

B. COTTONSEED CAKE

Animal feeding in all advanced countries is based on balanced rations calculated to maintain optimum nutritional requirements; much of the oilcake exported from this country must necessarily conform to their standards for protein and fat. It is hoped that the traditional use of whole cottonseed will give way to use of oilcake for feeding purposes. Achaya, Rao, Rao and Saletore[1] have emphasized the importance of the crude fibre content of oilcake as an index of the hull and protein content of cottonseed cakes, and have suggested tentative standards for the same.

In the U.S.A., the following categories are recognised:[5] (a) Cottonseed meal of various grades containing 38, 41, 43 and 45% protein or over (prime quality), all derived from decorticated seed; (b) Whole pressed cottonseed with a minimum guarantee of 28% protein. In the U.K., oilcake is purchased on guarantees of protein, fat and crude fibre.

It is important that similar standards be laid down and nomenclature adopted. As emphasised in the comments by Murti to an earlier paper,[4] fixing the protein content defines the nutritional quality, and would prevent the processing of whole seed. He also suggested that protein and fat should be stated separately rather than as protein + fat, and other characteristics like odour, mouldiness, etc. be included. It is desirable that cottonseed should not be crushed without removal of linters when these exceed 3-4% on the seed.

Conclusions

The concept and adoption of quality control and standards is of comparatively recent origin. It is an outcome of a highly-competitive market and also necessitated by the specific raw material requirements for modern industrial products. In cottonseed, we have an example where the development of the industry in this country greatly depends upon the markets for the three main products, linters, oil and cake. The establishment of graded standards when the industry is slowly gaining ground will provide an impetus to its developing on the right lines.

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DISCUSSIONS

Discussion Leader: Dr. S. A. Saletore,
Regional Research Laboratory,
Hyderabad.

General

S. A. Saletore. During the past few days the technological and practical aspects of cottonseed utilisation have been discussed thoroughly. Certain other aspects are just as important. These are the price of cottonseed and its products, the freight structure, the price and quality of linters, the policy of the Government with respect to excise duty and exports, and finally, the high cost of machinery for this industry.

Certain types of machinery like delinters, dehullers, and high-pressure expellers are not ordinarily used by the present oil industry and we have to examine whether they could be fabricated in India. (The discussion leader then summarized the papers submitted). I now throw the subject open for discussion as a whole, and not merely to the subjects covered in the papers submitted.

Equipment

G. S. Chowdhury. As far as I am aware cottonseed processing equipment like delinters and dehullers are not being fabricated in India. Far from being deterred by the idea of copying a new type of machine, the present restrictions on foreign exchange and imports should stimulate our engineers and industrialists to design and fabricate new machinery. Expellers are being made in this country but most of them are badly designed and fabricated resulting in loss of efficiency and in breakdowns. Provided sufficient attention is paid to quality there is nothing in the cottonseed processing machinery which cannot be fabricated in this country.

B. P. Maheshwari. Most of the equipment for oil mills purchased by me was well duplicated as long as 15 years ago, and is still giving efficient service.

G. S. Chowdhury. While I really congratulate the firm which has manufactured cottonseed equipment even 15 years ago, my only complaint is that basic attempts are not being made to improve our present fabrication techniques and to make quality material.

M. Narayana Rao. The Government of India have recommended the addition of 5% of *sesame* oil to vanaspati to detect its adulteration in ghee by the Baudouin test. Addition of 2.5% of cottonseed oil can also help detection of adulteration, substituting the Halphen test for the other. Addition of 5% cottonseed oil would perhaps be even better. Further, it has been reported that vitamin A in vanaspati slowly destroys sesamolin of the added *sesame* oil and thereby reduces the intensity of the Baudouin test.

F. G. T. Menezes. The difficulty experienced as a result of fluorescence in cottonseed oil appears to be of local origin and confined to the Calcutta area, and does not appear in cottonseed oils from seeds produced in other areas.

In advocating the Halphen test in place of the Baudouin test, Dr. Narayana Rao had stated that addition of sesame oil has a destructive effect on vitamin A in vanaspati. He is probably referring to the reverse effect which had been reported sometime back from a vanaspati factory in Ghaziabad, viz., that the presence of vitamin A in vanaspati has a destructive effect on the Baudouin test given by *sesame* oil. However, the work done in our own laboratory at Delhi and at the CFTRI and NCL was unable to confirm these findings, and in fact has clearly shown that the Baudouin test given by vanaspati is not in any way affected by vitamin A.

G. M. Borkar. The addition of refined or washed oils to vanaspati in place of hydrogenated oil is not satisfactory or desirable, since the quantity of cottonseed oil that could be used would be reduced and the colour of vanaspati would be increased. Further, the Halphen test is not as sensitive as the Baudouin test; the intensity of colour reading in the former is only 25% of that obtained in the latter test with equal additions of the two oils. Further the Halphen test is cumbersome and dangerous.

PAPER 1

T. V. Subba Rao. While I do not underestimate the technological problems of the cottonseed industry, its development today is largely an economic problem. There is a close relationship between changes in the economic situation and technological development. What will be the repercussions on the world market of a large increase in cottonseed oil production? We have to study the trends of different oils and oilseeds in the major producing countries.

Examining the world production of oil, the major contribution is by edible vegetable oils like groundnut, soya, sesame, olive, etc. Since these oils cannot be produced at the same rate as the population growth, there is an interchange between the different oils as regards end-use applications. There has been a rapid rise in the movement of cottonseed oil in the world market, from 17,000 tons in 1938 to about 36,800 tons now. In the world market there is an actual shortage of cottonseed oil and whatever cottonseed oil this country can produce should easily find a market. In our own interest it is advisable that we consume cottonseed oil and export groundnut oil which fetches a greater foreign exchange currency.

The relative price structure prevailing between cottonseed and its by-products is complicated: unless we can bring cottonseed oil into parity with groundnut oil it will continue to be a problem. Whereas cottonseed oil in the U.K. sells lower than groundnut oil, the price in India at various times may be Rs. 200 per ton above or below that of groundnut oil.

It would be desirable to apply operational research techniques to study the development of this industry. The major problems are in regard to improvement of the yields of oilseed, oil content and recovery of oil from the seeds. Solvent-extraction of cottonseed needs encouragement. Economic utilisation of the by-products of cottonseed is also important. I have already given relevant data in this connection in my earlier papers. In particular, work on cottonseed protein as a possible industrial raw material for fibre, adhesive and other high-polymer industries deserves periodic reconsideration. In India we have also still to consider the utilisation of cottonseed oil in the cooking and margarine industries.

Finally, if a major portion of cottonseed is indeed to be used for oil production, what alternative feeding stuff should be provided to cattle to make up the energy equivalent denied to them? After all oil gives about twice the energy obtainable from proteins or carbohydrates, weight for weight.

PAPERS 2 & 3

J. M. Shah. Contrary to the statement in papers 2 and 3, on experience it can be said that there is adequate demand for crude oil in the country. Crushers having Baby expellers but not washing vessels are confronted with difficulties, but there are ready buyers for crude oil in the market who have got washing facility and will buy crude oil.

In paper 3, I wonder whether the author has made out a case for himself or against himself! He is talking about the reduction of freight on cottonseed. Members present here are already aware that in the absence of cottonseed-mindedness amongst the farmers, it is difficult to sell the cake whereas he is advocating the reduction of freight on cottonseed. If the freight is reduced on cottonseed what will be the incentive left for the crushers? It will encourage among farmers the habit of feeding whole cottonseed instead of cottonseed cake. What is needed is that the freight on cottonseed should be enhanced so that cattle keepers may find the price of cottonseed cake relatively much cheaper to the price of whole cottonseed.

On the basis of the present crop of nine to ten lakh bales in Vidarbha, only one lakh tons out of the annual production of three lakh tons of cottonseed is consumed by the cottonseed crushing industry. Hence there is much scope still for the development of the industry in this area. Instead should an impetus be given for the export of cottonseed by way of reduction of freight, there would be an adverse effect on the development and growth of this industry whose main production is cottonseed cake, because in this particular oil industry the oil percentage is only 13 whereas the cake percentage is about 84 to 85. I would like to refer to some of the judgments which have been given by the railway tribunal and also by the High Court both in this country and also abroad. It is expressly agreed by the railway authorities that advantage will be given but the geographical position should not be nullified by giving indirect concession in railway freight. Hence I am strongly of the opinion that the freight on cottonseed should be increased so that cattle keepers may find the price of cottonseed cake relatively cheap compared with the price of cottonseed.

R. K. Bhatnagar. I feel that only a one-sided picture has been given. While most of the cottonseed is grown in the South, the majority of consumers, both for cake and oil, are in the North. It would be much easier to transport the solid seeds than the oils, and the cake separately. Such considerations have to be kept in mind while locating new industries, apart from regional considerations.

B. M. Jindal. At present the railway freight is the same on all oilseeds, though only 10-15% of oil can be extracted from cottonseed as compared with 40% from other oilseeds. We are therefore in effect paying more for cottonseed on equivalent oil basis. Further, cottonseed being a seasonal crop, reduction of freight would enable more crushers to obtain seed from other localities instead of its being used as cattlefeed where grown. More publicity and education is necessary to popularise the use of cake.

S. Zainul Abideen. Since more oil than seed can be transported per wagon, it is not at all necessary to reduce the freight on cottonseed. Cottonseed industries should be located in cotton-growing areas. If crude oil is to be transported some antioxidant must be found to prevent deterioration of oil during storage and transit. Road transport should also be encouraged to remove pressure on the railways.

G. V. Sirur. The question of freight rate is one of economics. Cattle feeders in this country do not grow cottonseed and the crushers or oil millers are not interested in finding out the exact demand. Today, cottonseed cake has to be transported nearly 1,400 miles from the source of production for use as cattlefeed. If the freight on seed is reduced what will be the fate of the producer? I feel that this move towards reduction in freight is dangerous. I do not think the Railway Board will accept the Planning Commission's recommendation, since geographical importance is only relative and subject to change.

Papers 4 & 5

S. A. Saletore. The methods of operational research are brought out in these papers.

Paper 6

K. S. Murti. I agree that standards should be laid down for linters and cottonseed cake. But I would suggest we wait till a large volume of statistical data is obtained before laying down any specifications. The object of specifications is to ensure quality and elimination of impurities. The objective may not be helped by inclusion of crude fibre standards for cottonseed cake. I am of the opinion that the crude fibre content will not help in the detection of adulteration of oilcakes with cottonseed cake and it need not find a place in the specifications. It is primarily the protein content that is important.

S. Raghavendar Rao. In our paper on linters we have tried to focus attention on the need for standardisation of linters. I do endorse Dr. Murti's contention that more data are required before standards are laid down. With reference to crude fibre in cottonseed cake, this problem was taken up at the instance of the Government of India, who were interested in fixing limits for crude fibre in cottonseed cakes. While I do not know if crude fibre determination could be practicable in detecting adulteration in oilcakes, it would certainly help in preventing the crushing of high-lintered seed without preliminary delinting. Crude fibre is of proved importance in the calculation of animal feed rations and is in fact a part of the standards laid down in the U.K. and U.S.A., which are based on protein, fat and crude fibre.

Conclusion

S. A. Saletore. Though India is one of the largest growers of cottonseed, the maximum exploitation of this raw material is not taking place since the proper machineries for the cottonseed industry are not available. In conclusion, may I say that the cottonseed crushing industry is not new and is already fully developed in the U.S.A. and on the Continent. We have to adapt their techniques and data to Indian conditions. The Government is in a mood to help the industry by removing excise duty, etc. At the same time, factors which really are important are not wholly technological, *e.g.,* competition between seed and the cake for cattle feeding. The merits of the oilcake need to be widely publicised and it is essential that all the oil be used in the country itself. What I foresee is that while the technology develops, the industrial development is bound to occur. Cottonseed industry will certainly see a phenomenal rise in the near future in much the same way as the vanaspati industry has developed. The question of stabilizing the industry is important and the economic aspects have to be gone into in greater detail.

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RESOLUTION AND THANKS

RESOLUTION AND THANKS

Resolution

Shri Baldev Singh, Convenor of the Symposium, moved the following resolution at the conclusion of the Symposium which was adopted unanimously after some discussion:

> "This gathering recommends that to ensure the prosperity of the cottonseed industry, similar meetings be held regularly, perhaps at yearly intervals, where all those connected with and interested in the industry could meet, exchange research and technical information and suggest measures likely to promote the well-being of the industry."

Thanks

Dr. K. S. Murti, Principal, Oil Technological Institute, Anantapur, moved a vote of thanks on behalf of all the participants at the Symposium for the excellent arrangements for and conduct of the Symposium, which was carried unanimously.

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